ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

Annual Review 1992/93

Alberta
ENERGY
Research and Technology Branch

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Preamble

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

The purpose of the Office is to coordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade.

Its goals are:

- to minimize the environmental impact of coal production, transportation and use in Alberta and elsewhere, with particular emphasis on coal-fired power generation;
- to enhance the competitiveness of Alberta coals in domestic and international markets; and
- to develop new uses for Alberta coals.

Appointed to the Office are J.K. Kleta as chairman, and G.T. Page, T.D. Brown, M.P. du Plessis and C.R. James as members.

Initial government funding for the Office was provided by the Alberta/Canada Energy Resources Research Fund (A/CERRF). Before this fund was fully depleted in 1991/92, it had supported 143 coal research projects. Current funding is being provided by the Alberta Department of Energy.

Introduction

Chairman's Report

During 1992/93, the Alberta Office of Coal Research and Technology continued to support coal research and technology development through the Alberta Coal Research Program and some projects in the Western Canadian Low-Sulphur Coal Program.

Most research projects managed by the Office were carried out and partly funded by the private sector and/or other governments and research institutions. This research is helping to strengthen an industry that contributes more than $500 million annually to Alberta's economy.

Thus far, the knowledge gained through coal research has helped lower the costs of finding, mining and preparing coal. This has allowed Alberta coal companies to maintain and expand their position in the marketplace even though the per-tonne income they received for coal declined and mines elsewhere were shut down. As one example, an Alberta government investment of $162,000 in a study of coal preparation plants has resulted in an improvement of up to five per cent in the performance of some plants. This is worth approximately $15 million a year to Alberta's bituminous coal sector.

All coal investigations were based on the Alberta Coal Research Strategy, originally developed in 1983 and subsequently revised in 1990 after considerable consultation with the coal industry and relevant government agencies. The research goals resulting from this consultation focus on the identification, investigation and development of technologies that will be commercially important in the period from 1995 to 2005. These technologies will:

- minimize the environmental impact of coal production, transportation and use in Alberta;
- enhance the competitiveness of Alberta coals in domestic and international markets; and
- result in new uses for Alberta coals.

These goals allow the Office to continue building upon its past activities and experience, and will require a continuing emphasis on the environmental aspects of coal production and use.

During 1992/93, projects funded by the Office helped several technologies to advance toward commercial applications. For example, in a project led by Fording Coal Ltd., a pilot plant has been constructed to test a coal/oil upgrading process. In addition, a major petroleum company may become involved in a project that has been under way at the Alberta Research Council to make carbon fibres from coal. As well, a field demonstration unit was built to test a low-cost, coal-based method for cleaning contaminated soil.

Current research priorities include:

Clean-Coal Technologies

- coal gasification, particularly Integrated Gasification Combined Cycle (IGCC);
- carbon dioxide (CO_2) use in enhanced oil recovery/disposal in aquifers; and
- technologies to reduce emissions of nitrogen oxides (NO_x) and trace elements.

Technologies to Enhance the Competitiveness of Coal

- reclamation of tailings ponds and open-pit mines;
- procedures for optimizing coal preparation plants; and
- injecting pulverized coal into blast furnaces.

New-Use Technologies

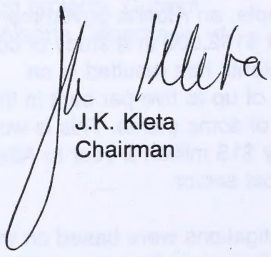
- coal/oil upgrading;
- coal/water fuels for power generation; and
- carbon fibre development.

The Office continued to provide administrative support to the Canadian Gasification R&D Steering Committee and the CO_2 R&D Coordination Committee (CORDNET). The Office also encourages collaboration among research and development organizations in Alberta, Canada and several other countries. Members of the Office continued to be involved in the National Advisory Council on Coal Research (NACCR), which comprises senior executives from the Canadian coal industry, federal and provincial governments and the research community.

Internationally, the Office continued to be involved in projects with Japan and several European countries through the International Energy Agency. The President of The Coal Association of Canada and the Chairman of the Office of Coal Research and Technology represented Canada and Alberta, respectively, at the International Committee on Coal Research (ICCR) meeting during September 1992 at York in Britain.

The Office members met four times in 1992/93, and were advised on the technical merits of project proposals by a Coal Research Review and Selection Committee. Members of this committee were: A. Turak (Alberta Energy), Chairman; D. Macdonald (Alberta Energy), Secretary; M. McDonald (TransAlta Utilities Corporation); R. Hermesh (Alberta Environmental Protection); V. Marwaha (Environment Canada); B. Paterson (ERCB); A. Vanderputten (Manalta Coal Ltd.) and E. Yildirim (Canadian Occidental Petroleum Ltd.). The committee met once to rank proposals and make recommendations for research funding during 1992/93.

Day-to-day administration of projects supported by the Office is provided by staff in the Research and Technology Branch of the Alberta Department of Energy. Additional assistance, cooperation and considerable support were received from the coal industry, research institutions and intergovernmental organizations.



J.K. Kleta
Chairman

Background

Alberta's coal industry provided an important energy source during early development of the province. It continued to contribute significant economic activity until about 1950 when the coal market collapsed because large amounts of oil became available as a replacement fuel.

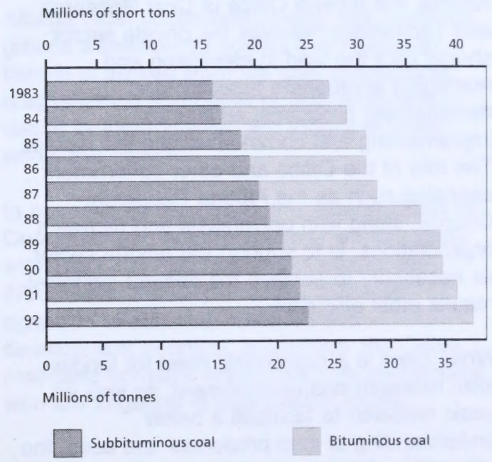
In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

Alberta's raw coal production rose steadily after 1975, reaching 35 million tonnes in 1989. In 1992, raw coal production increased to 38 million tonnes; nearly five per cent higher than the 1991 level of 36.3 million tonnes.

Today, Alberta is Canada's largest coal-producing and coal-consuming province. Its 12 major coalmines produce three types of coal for three different markets. Approximately two-thirds of total production is subbituminous coal produced from plains mines and used for power generation at mine-mouth, electricity-generating stations.

High-quality, bituminous metallurgical coal is produced from three mountain coalmines for export to the steel industries in Japan, Korea and Brazil. Low-sulphur, bituminous thermal coal is produced from two mines in the foothills region of Alberta for export to Ontario, Japan and Korea. Also, five small mines in the plains area of the province supply coal for the local market.

Raw Coal Production



Although the international coal market is still in an oversupply situation, several thermal coal-mines in the foothills region have been approved for development when warranted by export markets. Income earned by Alberta's coal producers is derived from exports of bituminous coals, and from subbituminous coals used by Alberta utility companies to produce nearly 90 per cent of Alberta's electricity. Approximately 2 350 people are directly employed by Alberta's coal producers.

While these statistics emphasize the importance and some of the benefits of Alberta's coal industry, there are other advantages to having a healthy coal industry in the province. For example, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to all levels of government, and the purchase of goods and services within Alberta. Some 6 100 Albertans are employed directly and indirectly by coal mining.

It is expected that Alberta's electricity production, based on low-sulphur coal, and the province's coal industry as a whole, will encourage the growth of secondary industries, provide a reliable and economic energy source for recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize their opportunities, however, coal-exporting companies must continue to capitalize on economic events in the marketplace. This was made more difficult for producers of metallurgical coal by a downturn in Japanese steel production in 1992 and a build-up of coal stockpiles in that country. On the other hand, Alberta coal shipments increased to Brazil and Korea. The income received for export coal improved somewhat, largely because of the lower Canadian dollar relative to other currencies. Some of the rise in raw coal production this year was in response to increased demand from the operators of Alberta's thermal electric plants. These facilities generated seven per cent more electricity in 1992 than a year earlier.

Today's market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies, such as agglomeration, coal-water fuels, and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these challenges is expressed in the Alberta Coal Research Strategy, published in November 1983 and revised in 1990. This document was the result of extensive discussions among individual companies and the provincial government. Following the initial round of discussions in 1983, the Alberta Office of Coal Research and Technology was established in 1984. Subsequent industry proposals that were submitted to the Office resulted in research and development projects funded jointly with the Alberta government.

Other research projects funded by the Office have been carried out by the Alberta Research Council (ARC) and the former Coal Mining Research Company.

An important function provided by the Alberta Office of Coal Research and Technology is the coordination of coal research and development activities within Alberta, as well as between Alberta and national and international agencies.

This activity has led to better integration among the various coal research groups in Alberta. It has also resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international cooperation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is both influencing and benefitting from coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels, and the Canada/Japan Coal Conversion Research and Development Committee.

Coal Research Strategy

Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for longer-term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources will be from 1995 to 2005. During this time, growth in thermal coal may be expected throughout the world. Alberta's share of this market will be influenced by

increased competition from other coal exporters. The extent to which this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, such as natural gas and oil, and the relative social and environmental acceptance of coal versus other fuels or nuclear power.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund (A/CERRF) of approximately $20 million in support of research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. When the A/CERRF funds were fully depleted in 1991/92, the actual contributions received from industry had exceeded $36 million.

A portion of the funding now available from the Alberta Department of Energy is being used for longer-term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada, the Alberta coal industry and coal research agencies to establish research and development priorities. In addition, the Office maintains contacts world-wide with researchers who are engaged in coal-related studies.

Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound management and financial control of approved projects. For each project, specific agreements are signed that define the terms and conditions under which the work will be conducted and funded. These agreements also define the respective rights to own and use new project technology.

After proposals have received thorough consideration, those falling within the interests of the Office are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research on their areas of responsibility. This group includes representatives from the Energy Resources Conservation Board and the departments of Environmental Protection, Economic Development and Tourism, and Labour.

Approval of research proposals by the Alberta Office of Coal Research and Technology takes into consideration the results of these reviews, as well as relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan.

Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred that could significantly affect Alberta coal producers, particularly those depending on export sales.

For example, Ontario Hydro is considering the use of more low-sulphur coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. At the same time, a new three-year contract between Ontario Hydro and Luscar Ltd. in Edmonton will reduce coal purchases from 1.8 million to 1.2 million tonnes a year. Nonetheless, both the coal-producing industry and government are committed to reducing the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to produce steam for enhanced oil recovery operations, while maintaining coal's position as the base load fuel for electricity generation.

World-wide, the development of new coal-use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology.

Currently, those priorities are as follows:

- to develop and apply clean-coal technologies that are cost-efficient and reduce the production of harmful atmospheric emissions;
- where there is a clear benefit to the Alberta economy, to develop and apply coal transportation technologies that will have a reduced effect on the environment; and
- to develop technologies that will improve coal production, quality and mining, and result in minimal disturbances of land and water bodies. This activity, too, must be economically beneficial to Alberta.

During 1992/93, several projects were under way that related to these objectives and also responded to the advice of the National Advisory Council on Coal Research.

Research and Technology Programs

During 1992/93, the projects administered by the Alberta Office of Coal Research and Technology were supported either by the Alberta Department of Energy in the Alberta Coal Research Program or by governments participating in the Western Canadian Low-Sulphur Coal Program.

Projects under way in these two programs are described in the following sections.

Alberta Coal Research Program

Clean-Coal Technologies for Electrical Power Production in Alberta

Currently, 88 per cent of Alberta's electricity is generated in coal-fired power plants using subbituminous coal. Of the remainder, 8.5 per cent is produced by using natural gas as fuel and 3.5 per cent is generated by hydro. The sulphur content of Alberta coal ranges from 0.3 to 0.7 per cent, which is among the lowest in the world. Nonetheless, the emissions resulting when Alberta subbituminous coal is burned are higher in sulphur oxides than are those produced when natural gas is used as the fuel. Furthermore, the price of natural gas has declined in recent years, reaching a level that makes it competitive with coal. Consequently, some serious consideration is being given in Alberta to the notion of using natural gas to replace coal in future electricity-generating stations.

By contrast, it can be argued that since Alberta's coal industry generates an annual revenue of approximately $500 million and directly employs 2 350, more damage would be done to Alberta's economy by allowing the domestic coal market to be eroded than would be gained by substituting one fuel for another. Furthermore, the technologies that would allow coal to be consumed as cleanly as natural gas already exist; they simply have not been demonstrated in Alberta thus far.

Considering these two positions, the industry and government participants in the Alberta Coal Research Program have chosen to support research projects that will help maintain coal as the base load fuel in Alberta's power plants, while achieving lower emissions and not losing the normal cost advantages of coal.

Ten projects relating to this subject were under way this year. They are described in the following subsection.

International Energy Agency Coal Combustion Science–Program Extension

NETHERLANDS ENERGY RESEARCH FOUNDATION ECN, PETTEN

Coal combustion testing at a semi-industrial scale has been under way for several years at the International Flame Research Foundation (IFRF) in The Netherlands. The objective of this work is to design burners for pulverized coal combustion that have acceptable combustion characteristics while producing few atmospheric pollutants.

This work, which is part of the International Energy Agency Combustion Science Research Program, is funded jointly by Canada, The Netherlands, the Federal Republic of Germany and Great Britain. The Canadian contribution has been divided among the Canada Centre For Mineral And Energy Technology (CANMET), the Canadian Electrical Association, and the Alberta Office of Coal Research and Technology.

Past work included: studies of the effects of coal blending on the performance of the Aerodynamically Air-Staged Burner (AASB) and scale-up of the AASB to 12 MW; effects of mixing on NO_x reduction; coal combustion characterization; modelling the in-flame data generated in scale-up trials; performing preliminary studies on the modelling of NO_x formation in coal flames; and fuel stage combustion using an internally fuel-staged burner.

During 1991/92, IFRF scientists began studying tangentially fired boilers, a subject that is particularly relevant to Alberta where tangential firing is used almost exclusively. Coal Valley coal was included in this study. This work was continued in 1992/93. The objective was to compare the performance of the AASB with the jet flames produced by tangentially fired boilers. This was done by investigating the effect of near-burner zone mixing and the stoichiometry.

A method was found for simultaneously evaluating the burners individually or in combination. While numerous parameters could be varied and controlled, it was found that most were highly dependent on each other. It did appear, however, that external air staging, which is analogous to using overfire air in tangential firing, was more effective than external fuel staging in reducing NO_x emissions.

Work continued in 1992/93 on developing methods for predicting the concentrations of nitrogen species in coal flames. The objective was to achieve a good match between measurements of temperature and bulk gas compositions in actual coal flames and the predictions made by a numerical flame model developed earlier at IFRF. After several modifications were made to the model, the match between predicted and measured values improved, but it is acknowledged that a closer match is required.

Publications

Dugué, J. and M.P. Abbott. 1989. LDA Measurement in Semi-industrial Gas and Coal Flames. Report on the AMT 1 Investigation. IFRF Document F 072/a/18.

Dugué, J., P. Ereaut, H. Horsman and A. Shand. 1990a. Laser Sheet Visualization in Cold Flows, Gas and Coal Flames in the IFRF Furnace No. 2. Results of the AMT 2 Investigations. IFRF Document F 072/y/19.

Dugué, J., P. Ereaut, H. Horsman and A. Shand. 1990b. Laser Sheet Visualization in Cold Flows and 2.5 MW Gas and Coal Flames. Report on the AMT 3 Investigation. IFRF Document F 072/y/20.

Knill, K.J. 1991. Fuel Staging and Its Implementation in a Novel Internally Staged Burner. Ph.D. Thesis. Technische Universiteit, Delft. International Flame Research Foundation.

Knill, K.J. (n.d.) The Effect of Mixing on NO_x Reduction by Coal Fuel Staging. IFRF Document F 37/y/21.

Knill, K.J., T.F.J. Maalman, M.E. Morgan and T. Nel. 1990. Characterization of the Combustion Behaviour of Bituminous Coals. Report on the CC 6 Investigation. IFRF Document F 088/y/12.

Morgan, D. J. and J. P. Smart. 1992. The Development and Testing of an Internally Fuel Staged Burner. Report on the AP23 Investigation. IFRF Document F 037/y/30.

Nakamura, T., J.P. Smart, W.L. van de Kamp and M.E. Morgan. 1990. Evaluation of the Behaviour of Blends in an Aerodynamically Air Staged Burner. Report on the AP 20 Investigation. IFRF Document F 037/y/22.

Nakamura, T., W.L. van de Kamp and M.E. Morgan. 1990. Evaluation of the Behaviour of Blends in an Air Staged Burner. Report on the AP 20 Investigation. IFRF Document F 037/y/23.

Peters, A.A.F. and R. Weber. 1991. The Development of a NO_x Postprocessor - A First Approach. Report on the MMF4-1 Investigation. IFRF Document F 036/y/17.

Sayre, A.N., K.J. Knill and J.P. Smart. 1991. Coal Characterization Requirements for Modelling Pulverized Coal Flames. Report on the CC7 Investigation. IFRF Document F 088/y/13.

Smart, J.P. and D.J. Morgan. (n.d.) The Comparison Between Constant Velocity and Constant Residence Time Scaling of the Aerodynamically Air Staged Burner. Report on the AP 22 Investigations. IFRF Document F 037/y/28.

Smart, J.P., W.L. van de Kamp and M.E. Morgan. 1989. The Effect of Scale on the Performance of the Aerodynamically Air Staged Burner. IFRF Document F 037/y/19.

van de Kamp, W.L., I. Ikeda and J.P. Smart. 1992. The Combustion of Pulverised Coal Using Simulated Turbine Exhaust Gas as Oxidant. IFRF Document F 037/y/29.

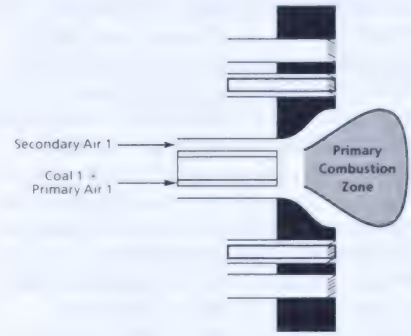
Visser, B.M. 1991a. Mathematical Modelling of Swirling Pulverized Coal Flames. Ph.D. Thesis. Technische Universiteit, Delft. International Flame Research Foundation.

Visser, B.M. 1991b. Tangentially Coal Fired Boilers - A Review. Results of the TFB1 Investigations. IFRF Document G 013/y/4.

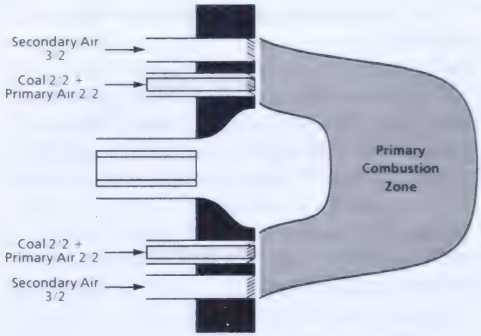
Visser, B.M. and R. Weber. 1990. Predictions of Near Burner Zone Properties of Six Swirling Pulverized Coal Flames. Report on the MMF 3 Investigation. IFRF Document F 036/y/14.

Woycenko, D.M. and J.P. Smart. 1993. Evaluation of a 2.5 MW Constant Residence-Time Scaled Version of a 12 MW Aerodynamically Air Staged Burner. International Flame Research Foundation. IFRF Document F 37/y/31.

TFB2 Burner Fired Under the AASB Mode



TFB2 Burner Fired Under the Tangentially Fired Boiler Mode



Coal Combustion and Gasification: Technology Transfer and Monitoring

ALBERTA RESEARCH COUNCIL, DEVON

After several years of collaboration with Japanese researchers on coal gasification and with the International Energy Agency (IEA) on coal combustion, the Office last year began a new activity to transfer all relevant research results to Alberta's coal industry. This service was provided by a combustion and gasification specialist from the Alberta Research Council (ARC).

During 1992/93, several technical presentations were made to Alberta's industry on recent results from the IEA combustion study and progress made in the collaborative work with Japanese researchers on coal gasification. Final reports on the IEA combustion work were obtained and distributed to Alberta's utility companies.

IEA Annex II meetings in The Netherlands and Great Britain were attended by ARC researchers. In July 1992, ARC hosted a visit and technical presentations by Japanese gasification experts who provided recent results from experiments using the Integrated Gasification Combined Cycle (IGCC) process developed by the Central Research Institute of Electric Power Industry (CRIEPI) in Japan. Two Japanese scientists worked for two months at ARC on various aspects of coal gasification research.

Arrangements were made to ship 50 tonnes of Coal Valley coal to the International Flame Research Foundation for combustion testing. Luscar Ltd. paid to ship the coal.

Funding for this project was provided by the Alberta Office of Coal Research and Technology and TransAlta Utilities Corporation.

Publications

Alberta Research Council. 1992. Third Quarter 1992/93 Report. Coal Combustion and Gasification Technology Monitoring and Transfer.

Chambers, A.K. 1992. Technology Transfer of IEA Annex II Coal Combustion Science Research - Fiscal Year 1991/92. Alberta Research Council.

Chambers, A.K. 1991. Coal Utilization Program Planning - Fiscal Year 1990/91. Alberta Research Council.

Chambers, A.K. 1990. Coal Utilization Program Planning - Fiscal Year 1989/90. Alberta Research Council.

Chambers, A.K. 1989. Coal Utilization Program Planning. Alberta Research Council.

Comparative Analysis of Advanced Power Generation Cycles

CANADIAN ELECTRICAL ASSOCIATION, MONTREAL

As a result of research carried out primarily in Europe and the U.S., several clean-coal technologies are on the verge of being demonstrated on a commercial scale. While this is good news for the environment, it is difficult for utility companies to choose the best technology for a particular application from the plethora of options. Thus, the Canadian Electrical Association, which represents all the power-generating companies in Canada, hired Bechtel Canada Inc. to make an assessment of the most promising technologies.

Altogether, approximately 50 technical options were assessed from the following categories:

- pulverized coal firing;
- fluidized-bed combustion;
- coal gasification combined cycle;
- mild gasification and topping cycle;
- Kalina cycle;
- gas turbine/combined cycle;
- fuel cells; and
- magnetohydrodynamics.

For each system, bituminous coal from eastern Canada, subbituminous coal from the Highvale mine and natural gas from Alberta were assumed to be the fuels. Locations for a 300-MW plant in eastern Canada and a 400-MW plant in western Canada were also considered. Eastern and western Canadian sources of any limestone used to capture sulphur oxides had to be included. The assessments were based on several criteria, such as energy-use efficiency, environmental performance, the time to commercial operation, operational flexibility, and key issues that could prevent or curtail further development.

The report resulting from this investigation includes the following data groupings for each technology:

- block diagrams of major process components;
- material and energy balances;
- performance summaries according to fuel type;
- Sankey diagrams; and
- cost estimates.

The information is available in the form of Lotus 1-2-3 spreadsheets. For access to the six-volume report (Project 9011 G 824), contact the Canadian Electrical Association at the following address:

Technology Department
Canadian Electrical Association
Suite 1600
1 Westmount Square
Montreal, Quebec
H3Z 2P9

Telephone: (514) 937-6181
Fax: (514) 937-6498

The project was funded by the Canadian Electrical Association, CANMET and the Alberta Office of Coal Research and Technology.

NO_x Optimization on Sheerness Unit #1

ALBERTA POWER LIMITED, EDMONTON, AND TRANSALTA UTILITIES CORPORATION, CALGARY

It is clear from the results of coal-combustion studies--particularly those carried out at the International Flame Research Foundation--that the production of nitrogen oxides (NO_x) during combustion depends on numerous factors.

These include the type of coal, the boiler design, various modes of feeding the coal to the boiler, quantity of excess air, whether overfire air is used, and other variables.

Most of the research reported in the literature, however, is for boilers other than the tangentially-fired types commonly used in Alberta power plants. Thus, the objective of this two-year project is to understand the influence of these various parameters on NO_x production during the operation of tangentially fired boilers. The work is being carried out at the Sheerness Unit #2 near Hanna, Alberta, which is owned jointly by Alberta Power Limited and TransAlta Utilities Corporation.

At year-end, the project was behind schedule, partly because a planned shutdown (when much of the equipment installation and modifications would be done) was delayed. New devices that would be used to balance the fuel flow to each burner had been ordered, however.

The project is being funded by Alberta Power Limited, TransAlta Utilities Corporation and the Alberta Office of Coal Research and Technology.

Full Fuel-Cycle Emissions Analysis – Preliminary Review of Existing Studies

MONENCO INC., CALGARY

In the ongoing debate about the effects of various emissions on the atmosphere, some people have claimed that fuels can be ranked according to the harm they do to the environment. One way for objectively assessing the relative merits of fuels is to carry out a "full fuel-cycle emissions analysis", which not only considers the effects on the environment of burning a fuel, but also includes environmental effects arising from:

- extraction and preparation of the fuel and its delivery to the power plant;
- construction of the power plant;
- manufacture of the equipment and chemicals used in the power plant; and
- power generation by the plant and all activities associated with the commercial operation of the plant, but not including environmental effects arising from power distribution.

Currently, the Alberta government is reviewing its policy (Electricity Fuel Use Policy) of favouring coal over natural gas as the base load fuel for generating electricity. To contribute to the review, the Alberta Office of Coal Research and Technology initiated a preliminary investigation of full fuel-cycle emissions analyses of the following power-generating systems:

- state-of-the-art pulverized coal firing;
- natural gas firing;
- hydroelectric;
- wind;
- solar; and
- waste firing.

Staff of Monenco Inc. (now Monenco AGRA Inc.) in Calgary carried out a review of the literature and other sources of information on current activities in this specialized field.

Although it was found that little information has been published on the subject, numerous power companies and government agencies are interested in the topic. The literature search revealed that considerable information is available on the emissions from certain aspects of power-plant operation, particularly combustion, but there is little on aspects such as construction, production of materials and the manufacture of equipment.

It was also apparent that there is considerable scatter in the existing data, largely because emissions tend to be specific to particular fuels, technologies and power-plant sites. Therefore, it was recommended that methodologies be developed for assessing emissions and allowing meaningful comparisons of various technologies.

Publication

Monenco Inc. 1992. An Initial Review of Existing Information and Reports on Full Fuel Cycle Emissions Analysis for Power Generating Systems in Alberta.

Canadian Coal Gasification R&D Project (CANMET/ARC)

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY, OTTAWA

In 1991, the Canadian Gasification R&D Steering Committee, a group of industry, academic and institutional researchers, initiated several gasification research studies under the Canadian Coal Gasification Project. All these studies will be carried out by the Canada Centre for Mineral and Energy Technology (CANMET) in Ottawa or the Alberta Research Council (ARC) in Edmonton.

Nine studies were carried out in the 1992/93 fiscal year. They dealt with the durability of materials, methods for controlling and reducing emissions, process enhancements to capture and use impurities, plant efficiency and methods for preparing coal feedstocks. These aspects were favoured by the private-sector members of the committee.

The reducing atmosphere present in gasification systems makes it necessary to use materials of construction that are different from those used in combustion systems. There is little information in the literature, however, about the characteristics of suitable materials. This is partly because modern-day gasification processes are quite new, and partly because the manufacturers of these systems consider materials science to be part of the proprietary aspects of their processes. In reviewing the existing literature and current developments, CANMET researchers and the committee concluded that the necessary expertise in materials science should be developed in Canada, with particular emphasis on ceramics for the gasifier refractory and alloys used in syngas coolers. These materials must be capable of withstanding the combined effects of halogens, sulphur and molten slag.

The effects of contaminants on turbines were also reviewed at CANMET. In particular, metals such as sodium, potassium, calcium, lead and vanadium can corrode the turbine components. This is especially relevant to low-rank western Canadian coals, which have significant amounts of sodium-, calcium- and potassium-containing compounds. Sulphur can also interact with alkali metals and chlorine to cause corrosion, but there is little concern about low-rank western Canadian coals in this regard because the sulphur content is low.

Related to these developments in materials science are the results of studying the performance of fluidized-bed combustion systems at some power-generating facilities in the Maritime Provinces. Here, erosion, rather than corrosion, was the principal problem.

By experimenting with different materials, plant operators found a suitable refractory or a spray coating that was capable of performing in a high-temperature environment. CANMET specialists believe that this experience is directly relevant to gasification systems.

Another major issue being addressed in this project is atmospheric emissions and their control. At the ARC, scientists identified the gaseous emissions of greatest concern, and they used two analytical methods to establish the lower detection limits of these substances.

The gases were: hydrogen sulphide, carbonyl sulphide, nitrous oxide, nitric oxide, nitrogen dioxide, carbon disulphide, hydrogen chloride, ammonia, hydrogen cyanide and methane. Fourier Transform Infrared (FTIR) spectroscopy and micro gas chromatography were used to analyse individual gases or gas mixtures of known concentration. Although these analytical methods are only two of many that could be used, they were chosen because they are relatively inexpensive and are believed to be suitable for routine applications in an operating coal gasification plant.

One or both analytical methods detected all the gases at concentrations as low as parts per million, and the analysis times were only a few minutes, making both instruments suitable for plant service. ARC staff recommended that field trials be initiated at operating gasification plants.

The composition of product gases is one of many variables that must be known when gasification technologies are being considered for a particular application. In turn, the gas composition depends on several factors, such as the coal used, the gasifier feed composition and the gasifier type.

In a study carried out at the ARC, scientists used a computer model to predict the effect of using limestone to remove some of the sulphur-containing components of the product

gas. The calculations were made using commercially available computer software (F*A*C*T) and known information about the performance of selected coals in three gasification systems: the commercial-scale Shell and KRW processes, and a lab-scale fluidized-bed gasifier at the University of British Columbia. Also, a sensitivity study was carried out to determine the effects on sulphur capture of temperature, pressure, gas composition and Ca/S ratio. This aspect of the work involved a Shell gasifier only.

Analysis of the likely sulphur capture when Highvale coal is used in a KRW gasifier indicated that 23-29 per cent of the sulphur should be captured, leaving a hydrogen sulphide (H_2S) concentration of 250 ppm in the product gas. This was consistent with an H_2S concentration of 200-210 ppm that was estimated by the equipment manufacturer.

Predictions for sulphur capture using the Shell process were made for five Canadian coals: Highvale, Paintearth, Costello, Minto and Cumberland.

The analysis indicated the following:

- gasifier pressure had little influence on sulphur capture;
- the maximum sulphur capture occurred at approximately 1 000°C for the five coals;
- sulphur dioxide (SO_2) emissions of less than 50 g/GL were possible for all the coals;
- the highest sulphur capture was predicted for the higher-rank, higher-sulphur coals; and
- the predicted sulphur capture decreased as the coal moisture content increased.

It was recommended that an experimental program be initiated to verify the sulphur-capture predictions.

CANMET researchers also used the F*A*C*T simulation software to determine the effect of temperature, steam and the ratio of oxygen to carbon on the gas components resulting from the gasification of coal. They found that the trends in the predicted distribution of components, such as carbon monoxide (CO), hydrogen (H_2), hydrogen sulphide (H_2S), carbonyl sulphide (COS), carbon disulphide (CS_2), hydrocyanic acid (HCN) and ammonia (NH_3), were similar to those measured during the operation of entrained-bed gasifiers.

The U.S. Environmental Protection Agency has identified arsenic and lead as priority elements in the context of controlling emissions. Thus, an attempt was made to predict the formation of arsenic- and lead-containing compounds when bituminous coals were gasified.
This was the first phase of a two-part experiment.

ARC computer specialists also reviewed several numerical simulation techniques that might be used to predict the outcome of reactions in a gasifier. After they examined six commercial products, they recommended that one made by Advanced Scientific Computing be used in a later study.

Meanwhile, CANMET scientists studied the effects of coal particle size and moisture on the conversion of carbon and hydrogen in an entrained-bed gasifier, and they measured the heating value of the produced gas, as well as the cold-gas efficiency. Highvale and Sheerness subbituminous coals and Shand lignite were used.

It was found that coal particles smaller than -100 mesh improved the reaction conditions. Some moisture in coal is also desirable, for it improved the conversion of carbon and hydrogen, raised the heating value of the gas and increased the cold-gas efficiency. There is a limit to this improvement, however, and CANMET scientists used their experimental results to define an upper level for the coal moisture content.

Earlier experiments supported by the Office showed that promising sorbents for removing unwanted sulphur compounds from gasifier

emissions can be prepared from the waste products of industry. This work is being continued at CANMET. Thus far, waste solids from the steel industry have been found to be as suitable as, or better than, commercial sorbents prepared from zinc ferrite. The iron- or calcium-containing wastes should not be used above 500°C, however. CANMET scientists also found that sulphur was removed efficiently by wastes from the nickel and copper industry. This is an important consideration because all the sulphur must be removed from any product gas that is used in high-temperature fuel cells.

FTIR Spectra: Location of Signal Bands for Calibration Gases

Gas	Wavenumbers (cm^{-1})
Water	3900—3500 1900—1300
Hydrogen Cyanide	3360—3240w
Methane	3150—2900s (3017) 1360—1240s (1307)
Benzene	3128—3009 (3062s) 1076—993 (1036) 710—633 (672s)
Hydrogen Chloride	3080—2640 (2820w)
Nitrogen Dioxide	2940—2860w 1650—1580s (1615)
Carbon Dioxide	2380—2310 (2350s)
Nitrous Oxide	2250—2180 (2225s) 1320—1250 (1285w)
Carbon Monoxide	2220—2050 (2170s)
Carbonyl Sulphide	2090—2030 (2060s)
Nitric Oxide	1950—1800 (2900s)
Carbon Disulphide	1550—1510 (1535s)
Sulphur Dioxide	1400—1300 (1360s) 1190—1100w
Hydrogen Sulphide	1330—1140w (1303, 1293, 1234)
Ammonia	1200—800 (930s)

(Source: Kovacik, G.J., A.K. Chambers, R. Zacharkiw and D. Ungarian. 1992. Emissions Analysis for Coal Gasifiers. Alberta Research Council.)

Among the front-running IGCC technologies that might be used in Alberta, the Shell process is capable of using coal as a dry solid. Processes developed by Dow and Texaco, however, are fed by coal-water slurries, which lower the inherent heating value of coal. In the case of subbituminous coal, the heating value of coal-water slurries can be too low even though this coal rank in dry form has been found to be the most desirable of the coal ranks available in Alberta. Therefore, ARC scientists reviewed the literature to determine how to increase the heating value of coal-water slurries made from subbituminous coals. This would allow these coals to be tested in the Texaco and Dow processes.

It was concluded that conventional techniques for increasing the solids concentration of slurries probably would not be sufficient to achieve the desired heating value. Consequently, other techniques may be required, such as:

- cleaning the coal to reduce the ash content;
- heating the coal above 200°C to reduce the equilibrium moisture and oxygen content;
- blending in a third, high heating-value component, such as bitumen; and
- using low-grade heat to evaporate the moisture before the slurry enters the gasifier.

More research was recommended.

In another study carried out this year, two anthracite coals from Alberta and B.C., plus three metallurgical coals from Nova Scotia, were gasified at CANMET to make activated carbon. Testing showed that the products were comparable to commercially available activated carbon in their ability to remove SO_x and NO_x from flue gases. Products made at CANMET also showed some promise for removing H_2S and COS.

The project is being supported by: TransAlta Utilities Corporation, SaskPower, Alberta Power Limited, Ontario Hydro, Edmonton Power, Nova Scotia Power Inc., ARC, Nova Scotia Department of Natural Resources, the Cape Breton Development Corporation, Environment Canada, CANMET, and the Alberta Office of Coal Research and Technology.

Publications

Chambers, A.K., B. Özüm, D. Fong and G.J. Kovacik. 1992. Coal Water Slurry Technology - A Literature Review of Production of High Solids Content with Low-Rank Coals. Alberta Research Council. Prepared for members of the Canadian Coal Gasification R&D Project.

Chambers, A.K., B. Özüm and G.J. Kovacik. 1992. Evaluation of Numerical Simulators for Coal Gasification. Alberta Research Council. Prepared for members of the Canadian Coal Gasification R&D Project.

Furimsky, E. 1992a. Materials Problems in Coal Gasification. Final Report. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Furimsky, E. 1992b. Effect of Moisture Content and Particle Size on Gasification of Low Rank Coals. Final Report. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Furimsky, E. 1992c. Effects of Contaminants on Turbine Performance. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Furimsky, E. 1992d. CANMET's Hot Gas Clean-Up R&D Program. Review/Update. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Kovacik, G.J., A.K. Chambers and D. Fong. 1992. Equilibrium Sulfur Capture Studies. Alberta Research Council. Prepared for members of the Canadian Coal Gasification R&D Project.

Kovacik, G.J., A.K. Chambers, R. Zacharkiw and D. Ungarian. 1992. Emissions Analysis for Coal Gasifiers. Alberta Research Council. Prepared for members of the Canadian Coal Gasification R&D Project.

Palmer, A. 1992. Report on the Properties of Activated Carbon for Cleaning Flue Gas from Combustion. Final Report. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Razbin, V. 1992. An Overview of CANMET Experience with Materials in Fluidized Bed Combustion Systems. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Zheng, L., F. Baudreau and E. Furimsky. 1992. Quantification of Gasification Products and Emissions by Thermodynamic Equilibrium Calculations Using the F*A*C*T Method. Final Report. CANMET. Prepared for members of the Canadian Coal Gasification R&D Project.

Stress Corrosion Cracking Evaluation in Coal Gasification Simulated Environment

THE UNIVERSITY OF CALGARY, CALGARY

The materials used to construct coal gasification plants are exposed to more extreme operating conditions than those normally encountered in conventional power plants. Some components must perform reliably at high temperatures in a corrosive environment, while others experience low-temperature, aqueous conditions. Therefore, the challenge is to select appropriate materials of construction that are long-lasting and relatively inexpensive.

Researchers believe that stress corrosion cracking under aqueous conditions is the principal cause of failure in materials. Erosion is another major cause of problems. Thus, a research project was begun at The University of Calgary to identify materials that are most resistant to stress corrosion in a coal gasification environment.

Several alloys were exposed to an aqueous mixture (comprising chloride, bicarbonate, sulphate and sodium ions) and a gaseous mixture of carbon monoxide, carbon dioxide, methane, hydrogen, hydrogen sulphide and nitrogen. The composition of the gaseous mixture was based on experimental results from the gasification of Highvale coal in a Shell gasifier.

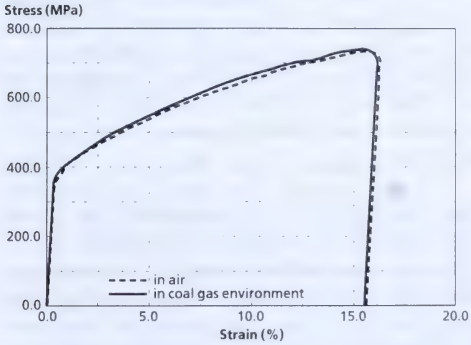
The exposed samples were also subjected to controlled rates of strain or tension, and the resulting fracture surfaces were examined by scanning electron microscopy (SEM) and optical microscopy.

Thus far, carbon steel, an iron-manganese-aluminum alloy and Hastelloy C276 (high nickel content) have been tested. It was found that both the carbon steel and the iron-manganese-aluminum alloy were susceptible to stress corrosion cracking. They experienced failure in the aqueous environment that was premature

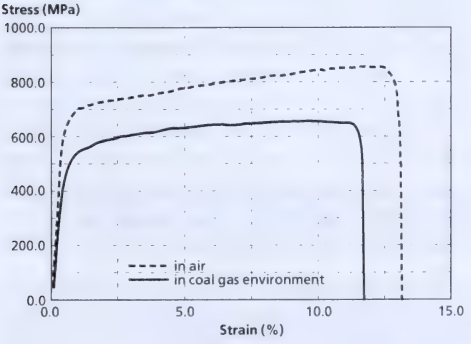
relative to their behaviour in an air-only environment. The Hastelloy C276, however, had a high resistance to stress corrosion cracking.

Funding was provided by Alberta Power, TransAlta Utilities Corporation, CANMET and the Alberta Office of Coal Research and Technology.

Stress-Strain Curve of Hastelloy C276 in Two Environments



Stress-Strain Curve of Fe-Mn-Al Alloy in Two Environments



(Source: Mao, X. and W.J.D. Shaw. 1992. Progress Report on Research of Stress Corrosion Cracking of Gasifier Vessel Steels in a Coal Gasification Environment. Department of Mechanical Engineering, The University of Calgary.)

Publication

Mao, X. and W.J.D. Shaw. 1992. Progress Report on Research of Stress Corrosion Cracking of Gasifier Vessel Steels in a Coal Gasification Environment. Department of Mechanical Engineering, The University of Calgary.

IEA Greenhouse Gas R&D Programme

INTERNATIONAL ENERGY AGENCY, UNITED KINGDOM

Thirteen countries, including Canada, are funding a three-year investigation called the Greenhouse Gas R&D Programme. This is a project of the International Energy Agency. The objective is to assess technologies capable of reducing the amount of carbon dioxide (CO_2) produced per unit of energy output from power stations that use coal or other fossil fuels. Alberta is contributing through Natural Resources Canada.

The candidate technologies either increase the thermal efficiency of combustion so that less CO_2 is produced, or capture the produced CO_2 and use or dispose of it. In this project, the feasibility of using various technologies is being determined. Proposals will then be prepared for further research, development and demonstration. The economic effects of implementing such technologies will be determined, with particular emphasis on the energy market. The work will be based primarily on coal-fired systems, but oil- and natural gas-fired systems will be included where appropriate.

Several energy-research agencies, consultants and contractors in supporting countries were contracted this year to prepare reviews of various technologies. Four of these studies concerned the production of carbon dioxide and other greenhouse gases by individual power-generation systems. The systems were: integrated gasification combined cycle; pulverized coal firing plus flue gas desulphurization; pulverized coal combustion in an atmosphere of O_2 and recycled CO_2; and natural gas-fired combined cycle. In these baseline studies, the cost of using specific gas cleanup equipment and the expected effects on emissions and efficiency were determined so that comparisons might be made in later studies of CO_2-removal technologies.

The principal options that now exist for CO_2 use or disposal were reviewed and reported.

Publications

International Energy Agency. 1992a. The Characterisation of Carbon Dioxide and Other Greenhouse Gas Releases from a Pulverised Coal Fired Power Plant Equipped with Flue Gas Desulphurisation Facilities. Prepared by British Coal Corporation for the IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992b. The Characterisation of Carbon Dioxide and Other Greenhouse Gas Releases from an Integrated Gasification Combined Cycle Plant. Prepared by the Netherlands Energy Research Foundation for the IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992c. The Characterisation of Carbon Dioxide and Other Greenhouse Gas Releases from a Natural Gas Fired Combined Cycle Power Plant. Prepared by The Norwegian Institute of Technology and SINTEF-Applied Thermodynamics for the IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992d. The Characterisation of Power Generation by Combustion of PF Coal in an Atmosphere of O_2 & Recycled CO_2. Prepared by Centre for Energy Research, University of Ulster for IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992e. Preliminary Review of CO_2 Disposal and Utilisation Options.

International Energy Agency. 1992f. Carbon Dioxide Capture: An Examination of Potential Cryogenic Technologies for the Collection of CO_2 and Other Greenhouse Gases Arising from Power Generation Using Fossil Fuel. Prepared by INTECH Inc. for IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992g. Carbon Dioxide Capture: An Examination of Potential Absorption Technologies for the Collection of CO_2 and other Greenhouse Gases Arising from Power Generation Using Fossil Fuel. Prepared by H&G Process Contracting Limited for IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992h. Carbon Dioxide Capture: The Characterisation of Gas Separation/Removal Membrane Systems Applied to the Treatment of Flue Gases Arising from Power Generation Using Fossil Fuel. Prepared by TNO for IEA Greenhouse Gas R&D Programme.

International Energy Agency. 1992i. Carbon Dioxide Capture: An Examination of Potential Gas-Solid Adsorption Technologies for the Collection of CO_2 and Other Greenhouse Gases Arising from Power Generation Using Fossil Fuel. Prepared by Monenco Inc. for IEA Greenhouse Gas R&D Programme.

Investigation of Aquifer Disposal of CO_2-rich Gases

STANLEY INDUSTRIAL CONSULTANTS LTD., CALGARY,
AND ALBERTA RESEARCH COUNCIL, EDMONTON

Coal-fired power plants are believed to contribute 30 per cent of all carbon dioxide (CO_2) in Alberta that arises from fossil fuel production and use. One option for reducing these emissions is to use coal-combustion processes that produce fewer emissions. Another option is to capture any emissions that are produced and either use the CO_2 productively or store it in natural underground formations.

The possible use of this captured CO_2 in enhanced oil recovery schemes is being investigated in another study. This would be an acceptable option as long as there is oil to be recovered. In the long term, however, another approach may be needed. Therefore, in this project, the technical feasibility of injecting CO_2 into underground aquifers is being investigated by Stanley Industrial Consultants Ltd., in cooperation with the Alberta Research Council (ARC).

The objectives of this "proof-of-concept" study are to:

- define the hydrogeology and the potential for CO_2 injection into aquifers in the vicinity of some Alberta coal-fired power plants;
- define the chemistry and the CO_2-trapping potential of typical Alberta calcitic or dolomitic limestone and silicate aquifers; and
- develop preliminary designs and conceptual cost estimates to implement an aquifer-disposal scheme.

A geographical area near the Sundance and Genesee power plants was selected to determine the locations of aquifers that best represented suitable disposal sites. Regional siliciclastic and carbonate aquifers were identified at depths between 1 400 metres and

2 000 metres in the Alberta Basin. Computer modelling of CO_2 injection into these aquifers showed that the disposal of 1 000 tonnes per day per well was achievable.

The available data from 754 wells in the area were culled, and two waters were chosen as representing the area: one brine and the other brackish. These two waters were used as the basis for computer modelling experiments to predict the likely reactions of CO_2 with the water under various conditions of temperature, pressure and other parameters. The objective was to identify the formation water and mineralogy that would result in the maximum storage of CO_2.

When CO_2 is injected into an aquifer, it will either react with dissolved minerals to form soluble bicarbonates or be precipitated as a carbonate mineral. Thus, ARC scientists used an existing database of geochemical information to define the ideal silicate and limestone aquifers where these reactions would occur. One of the pertinent findings resulting from the computer models was that the presence of clays can cause greater quantities of CO_2 to be captured, particularly in siliciclastic (containing mostly silicate minerals) aquifers. This occurs by precipitation of calcium-magnesium carbonate minerals. The modelling results indicated that brackish and dilute formation waters can take up more CO_2 than brine formation waters, and the maximum amount of CO_2 can be trapped in a siliciclastic aquifer containing a brackish formation water.

Following the computer modelling phase, laboratory experiments were carried out to confirm the computer predictions. Actual aquifer solids extracted from wells in the designated area were used to simulate formation water and then CO_2 was introduced under controlled conditions in batch reactors. The solubility of CO_2 in the water, reactions with the aquifer solids and the immobilization of CO_2 over a one-month period were measured.

In these studies, the reactions failed to reach equilibrium; the changes in solids were small and the total amount of trapped CO_2 was modest relative to the total possible amount. The few changes in mineralogy that occurred in the batch reactor studies were consistent with the geochemical modelling and the water chemistry. These mineral-trapping reactions are kinetically very slow, but given the low regional flow rate (cm/yr) and the large size of the Alberta Basin, CO_2 would be hydraulically trapped for thousands of years in aquifers. This is ample time for the CO_2 mineral-trapping reactions to take place.

In examining the engineering aspects of CO_2 injection, it was concluded that disposal of 15 000 tonnes a day would incur a capital cost of $2 200 per tonne per day of disposal capacity. The equipment needed for CO_2 capture and compression would add to this cost.

The project is funded by TransAlta Utilities Corporation, Edmonton Power, Environment Canada, CANMET and the Alberta Office of Coal Research and Technology.

Publication

Gunter, W.D., E.H. Perkins and T.J. McCann. 1993. Aquifer Disposal of CO_2-Rich Gases: Reaction Design for Added Capacity. Proceedings of the IEA Carbon Dioxide Disposal Symposium, Oxford, England, March 29-31, 1993.

Gunter, W.D., E.H. Perkins, S. Bachu, D. Law, B. Wiwchar, Z. Zhou, and T.J. McCann. 1993. Aquifer Disposal of CO_2 Rich Gases in the Vicinity of the Sundance and Genesee Power Plants. Alberta Research Council and Stanley Industrial Consultants Ltd.

CO_2 Disposal Study–Phase II

ALBERTA OIL SANDS TECHNOLOGY AND RESEARCH AUTHORITY, CALGARY, AND OTHER PARTICIPANTS[1]

In this project, which began in mid-1991, the objective was to determine the feasibility of disposing 50 000 tonnes per day (t/d) of carbon dioxide (CO_2) in a range of reservoirs in Alberta and Saskatchewan. It was assumed this would begin in the year 2000 and continue for 15 years. As much as possible, the CO_2 should be used to enhance the recovery of oil from some of these reservoirs. Any CO_2 not used for enhanced oil recovery (EOR) would be disposed of in depleted gas reservoirs.

At the end of 1992, three subprojects had begun. They concerned:

- the capture of CO_2 at sources that include coal-fired power plants, an ethylene plant, a sour gas plant and a hydrogen plant;
- analysis and predictions about the performance of light and heavy oil reservoirs in Alberta and Saskatchewan for enhanced and heavy oil extraction using CO_2; and
- the cost/benefit relationship for CO_2 recovery and use for each of the sources.

Seven cases were developed for CO_2 capture. Coal-fired power plants are well represented since they generate a significant portion of all CO_2 emissions in the two provinces (one-third of CO_2 emissions in Alberta). The oil and gas industry is another major source. In Alberta, it also generates one-third of CO_2 emissions and is represented in the remainder of the cases.

The investigators concluded that it is technically feasible to capture CO_2 from these sources. The data indicated that 88 per cent of the CO_2 that might be captured over 15 years could be used for EOR.

This could enhance oil production by more than 10 per cent, representing 20 000 cubic metres per day (m^3/d). The balance of the captured CO_2 would be deposited in depleted gas reservoirs.

This conclusion was based on data supplied by individual oil and gas companies about selected reservoirs in Alberta and Saskatchewan. These reservoirs represent the two most common types in western Canada: reefs and sandstones. Both have the characteristics required for CO_2 storage, namely porosity to provide space for fluids, permeability to allow fluid flow, and a seal impermeable over geological time.

The economic analysis considered 344 different cases, involving 10 CO_2 sources, three pipeline systems, eight EOR fields and one depleted gas field. Each of these was analysed using four economic approaches to determine the cost of delivering CO_2 to an oil field and the cost that an oil company could afford to pay for using the delivered CO_2 to recover an incremental quantity of oil. There was considerable variation in the differential between these two costs, depending on the CO_2 source, the EOR field, the oil price and the method of economic analysis. For typical cases, using the "normal business approach" of economic analysis, the affordable price was $32 per tonne (t), whereas the delivered cost was $57/t, leaving a negative differential of $25/t. One exception was the case of integrated gasification combined cycle, which would produce a positive differential of $2-$5/t.

The CO_2 capture costs were estimated to range from $25/t to $70/t. The capital cost to meet the target quantity of 50 000 t/d was estimated at $7.5 billion. This includes the equipment for both CO_2 capture and EOR. These costs could be offset by revenues from incremental oil recovery.

[1]A consortium of 25 companies and government agencies is funding the project under the leadership of AOSTRA.

Seven Case Studies

Case No.	Location	CO_2 Source	SO_x/H_2S Capture Technology	CO_2 Capture Technology	CO_2 Conc. (%)	CO_2 Available (t/d)	CO_2 Captured (t/d)	Capital Cost US$MM	Operating Cost US$MM/Y
1	Boundary Dam, Sask.	Coal-fired power plant	Andersen 2000	Amine	14	8 927	8 034	502	62.0
2	Sundance, Alberta	Coal-fired power plant	Dravo Lime	Amine	14	41 500	37 440	2 265	273.0
3	Joffre, Alberta	Natural gas combustion	N/A	Amine	8	3 717	3 345	142	41.0
4	Hanlan Robb, Alberta	Sour gas processing	Selexol	Amine	10	1 023	840	54	8.6
5	BP Upgrader, Sask.	Hydrogen plant vent	N/A	Amine	47	1 033	1 026	66	12.6
6	Sundance, Alberta	Coal-fired power plant	Dravo Lime	Argonne	80	41 600	37 440	2 704	246.0
7	Alberta	IGCC power plant	Selexol	Selexol	35	10 481	8 487	295	19.7

(Source: AOSTRA)

Technologies to Enhance the Export of Alberta Coals

Approximately 60 per cent of the total revenue generated by Alberta's coal industry is derived from selling coal in Central Canada and more than 12 countries. Consequently, it is important that coal producers be keenly aware of the requirements of their customers and the forces that are affecting those requirements. While economic conditions have always been the major driving force, environmental pressures are now becoming significant as well.

There are many opportunities to be explored. For example, virtually anything that Alberta coal producers can do to lower the costs of mining, preparing and shipping coal will help enhance their position in the international marketplace. In addition, the development of clean-coal technologies that achieve the desired results and perform well using Alberta coals could lead to a new industry in Alberta that manufactures equipment for export and simultaneously increases overseas sales of Alberta coal.

These two examples illustrate the significance of supporting research that aims to improve exports of Alberta coals. During 1992/93, this activity within the Alberta Coal Research Program encompassed four projects, which are described in the following subsection.

Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment

ALBERTA RESEARCH COUNCIL, DEVON

For the past year, scientists at the Alberta Research Council (ARC) have been studying the effects on the environment of virtually every chemical element released from coal when it is burned. Major, minor and trace elements of coal and coal ash are being examined. While most of the work is being carried out at ARC, two other agencies[1] are also providing expertise.

In Phase I, 119 coal samples were analysed. Eighty-two were borehole samples from the Highvale mine, and 20 were removed directly from an exposed seam at the Vesta mine. Elemental analyses were performed by Geocon Environmental Consultants of London, Ontario, and proximate analyses were done by the Geological Survey of Canada in Calgary. Petrological determinations were made at ARC.

Environmentally hazardous elements, such as arsenic, molybdenum, uranium and selenium, are inorganically bound and closely follow the ash content of the coals and interburden layers. It was observed that coal cleaning, which reduces the mineral matter content, will remove most of the elements that are inorganically bound. Organically bound elements, however, will be more difficult to remove.

Of the elements that were found, all except bromine are present in low concentrations and are within a range that is acceptable world-wide. The complete results, presented in more than 190 pages of tables and figures in three reports, provide a useful reference for future work.

[1]Funding in kind is being provided by the University of Western Ontario and the Geological Survey of Canada. TransAlta Utilities Corporation and the Alberta Office of Coal Research and Technology are providing additional funding.

Publications

Alberta Research Council. 1993a. Impact of Quality on the Utilization Potential of Alberta Subbituminous Coals. Submitted to Alberta Office of Coal Research and Technology and TransAlta Utilities Corporation.

Alberta Research Council. 1993b. Impact of Coal Quality on the Utilization Potential of Alberta Subbituminous Coals. A Progress Report. February 1993.

Alberta Research Council. 1992a. Impact of Coal Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment. A Progress Report. May 1992.

Alberta Research Council. 1992b. Impact of Coal Quality on the Utilization Potential of Alberta Subbituminous Coal. A Progress Report. October 1992.

Evaluation of the Suitability of Alberta/Canadian Coals for Blast Furnace Injection

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY, OTTAWA.

Until pulverized coal injection was developed on a commercial scale, non-coking coals could not be used as fuels in blast furnaces. Now, poor coals or those that are non-coking are commonly used for this application, largely because the injection of pulverized coal directly to the hearth of the furnace decreases coke consumption and improves the furnace performance.

Currently, 60 blast furnaces in 14 countries use Pulverized Coal Injection (PCI). In Japan, for example, PCI is used on 25 of 35 existing blast furnaces, and the quantity of coal injected per unit of produced steel (expressed as hot metal) has been rising steadily.

Since PCI technology is affecting the traditional coal markets, decreasing the demand for metallurgical coal and increasing the demand for cheaper coals, the coal market will become more competitive. This means that Alberta coals and other Canadian coals need to be assessed for their suitability in blast furnace injection to keep pace with the marketplace.

Generally, the suitability of coals for blast furnace injection is influenced by combustibility, cooling and coke-replacement properties. The combustibility of coal can be assessed experimentally. It depends on factors such as volatile matter content, soot formation, inert macerals, mineral matter content and composition, and the microstructure of char. Cooling and coke-replacement properties can be determined by mathematical modelling and simulation that takes into account the cooling effects of using non-coking coals.

To determine the suitability of non-coking Alberta/Canadian coals for use in blast furnaces, a study was undertaken by Canada Centre For Mineral And Energy Technology (CANMET). This year, the focus was on cooling and coke-replacement properties. A computer model of the blast furnace process, developed previously by CANMET, was used in this project. It is based on principles of mass and energy conservation for the steady-state continuous process. The model includes mass balance equations that account for carbon, oxygen and iron, as well as enthalpy balance equations which account for the bottom zone of the furnace and the combustion zone. One aspect of concern is the "raceway adiabatic flame temperature" (RAFT), which can be controlled by adjusting the type and amount of coal. Cooling and coke-replacement characteristics are influenced by the hydrogen and oxygen contents of coal, and can be expressed as the C/H and C/O ratios. The higher the C/H and C/O ratios, the smaller the cooling effect. Thus, greater quantities of coal can be injected without having to make a significant compensation in the blast furnace temperature.

Sixty-five coals, including 23 from Alberta, were evaluated and compared with foreign coals and other injectants (oil, tar and natural gas). CANMET researchers found that anthracite can be injected in the largest quantities without requiring any compensation in the blast furnace temperature. It was followed by bituminous and subbituminous coals, which were followed by oil. Natural gas had the greatest cooling effect. Ash content in coal is also important; higher ash content reduces the coke replacement and productivity of the furnace.

When compared with foreign coals, Canadian coals produced favourable or superior results. Canadian anthracites had lower cooling effects than those produced by a Chinese anthracite. While a French anthracite had a lower cooling effect than Canadian coals, the latter had the highest coke replacement ratios. Low-volatile bituminous coal from Alberta had lower cooling effects than those produced by coals from Australia, South Africa, Poland and the U.S. While Alberta subbituminous coals produced relatively high cooling effects and low coke replacement ratios, they generated high concentrations of calcium oxide in the ash, which can be beneficial in the slagging process.

While the computer evaluations indicated that all Alberta/Canadian coals should behave well in blast furnaces, their overall suitability is also influenced by combustibility characteristics. These properties will be determined next year through an experimental program.

The project was supported by the Canadian Carbonization Research Association and the Alberta Office of Coal Research and Technology.

Publication

Hutny, W.P. and L. Giroux. 1993. Evaluation of the Suitability of Alberta/Canadian Coals for Blast Furnace Injection Based on a Computer Model. CANMET.

A Comparative Study of the Cost and Environmental Benefits of Coal-Liquid Fuel and Coal Preparation and Utilization in Electric Power Plants

CANADIAN ELECTRICAL ASSOCIATION, MONTREAL

One way to reduce the undesirable emissions produced when coal is burned is to clean the coal using a process called "deep cleaning". This involves grinding the coal into fine particles and treating them in an aqueous slurry. Coal treated in this manner cannot be used directly as a fuel because the water and coal must first be separated. Nonetheless, if deep cleaning is to be used, it is logical to proceed with one additional step and make a coal/water fuel in which emulsifiers are used to keep the coal in suspension. Fuels of this type look and behave like fuel oil, and their preparation has been studied for years. One example is the DENSECOAL coal/water process, which has been used successfully with Alberta coals. In addition, other processes have been developed for mixing coal with water or other liquids, such as methanol. Some of these processes have reached the commercial stage. Collectively, all these processes are said to produce coal/liquid fuels.

Given the potential environmental benefits of coal/liquid fuels and their ability to behave like fuel oil for less cost than oil, a study was undertaken this year to compare the costs and environmental implications of coal/liquid fuels with solid coals that had been prepared in conventional and modified coal preparation plants. The Canadian Electrical Association (CEA) was the lead agency for this study, but the research was subcontracted to Neill and Gunter (Nova Scotia) Limited in Dartmouth.

According to the investigators, federal emission standards that will apply to new power plants after January 1, 1995 will largely affect nitrogen oxides (NO_x) and carbon dioxides (CO_2) emission limits, but organic substances and trace elements will probably be subjected to more stringent standards. In addition, these and other requirements may become even more strict in the year 2000.

The investigators then examined the technical aspects of four coal-delivery scenarios. They were:

- run-of-mine coal;
- conventional coal cleaning to remove some ash and some pyritic sulphur;
- advanced coal cleaning to produce a higher-quality product having even less ash and sulphur; and
- coal/liquid fuel production to make a fuel that avoids the need for a drying stage.

After the technical issues had been discussed, costs were assigned to each of the four processes for western Canadian and eastern Canadian bituminous coals. Added to these costs were those pertaining to coal handling, transportation and power-plant modifications to meet the proposed 1995 environmental regulations. Similar calculations were made for new power plants that become operational in 1995. Calculations were made for the following operations:

- conversion of existing coal-fired plants;
- conversion of existing oil-fired plants;
- construction of new conventional plants;
- construction of atmospheric circulating fluidized bed plants; and
- construction of integrated gasification combined cycle plants.

Since these estimates were prepared for all coal-burning regions of Canada, power companies are advised to consult the final Neill and Gunter report for the appropriate cost information.

Copies of the three-volume report for CEA Project 9015 G 867 are available from:

Technology Department
Canadian Electrical Association
Suite 1600
One Westmount Square
Montreal, Quebec
H3Z 2P9

Telephone: (514) 937-6181
Fax: (514) 937-6498

Ask for:

A Comparative Study of the Cost and Environmental Benefits of Coal-Liquid Fuels and Coal Preparation for Utilization in Electric Power Plants.

The project was supported by the CEA, CANMET and the Alberta Office of Coal Research and Technology.

Publication

King, B.W., D.B. Lawrence, M.W. Mikhail, R.A.S. Brown, G. Zhou and D.M. Rankin. 1993. A Comparative Study of the Cost and Environmental Benefits of Coal-Liquid Fuels and Coal Preparation for Utilization in Electric Power Plants. Neill and Gunter (Nova Scotia) Limited.

Development of Sport Fisheries in Lakes Created by Coal Mining Operations in the Eastern Slopes

LUSCAR STERCO (1977) LTD., EDSON

When coal extraction ceases in an Alberta surface mine, the open pit that remains must undergo some type of reclamation to restore the land to productive use. In mountain and foothills mines, much of the overburden is rock. This makes it impractical and prohibitively expensive to fill in a pit.

In two of the coal mining areas where Luscar Sterco (1977) Ltd. and Cardinal River Coal Ltd. have operated mines, three of the former pits have been allowed to fill with water and become lakes. Because both companies plan to develop other lakes in the future, a study was initiated in 1991/92 to investigate the three coalmine lakes and one natural lake to assess how best to develop these types of lakes for sportfishing and other recreational pursuits.

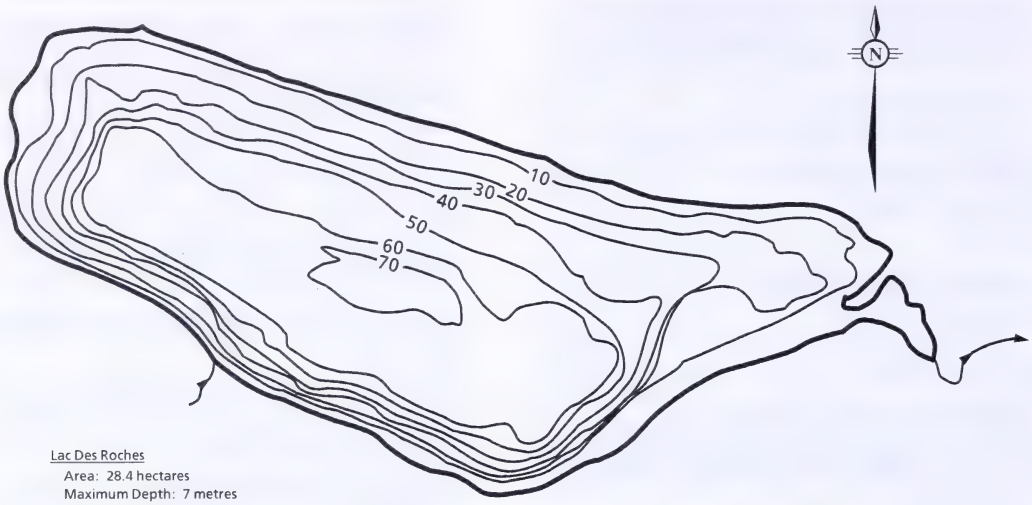
In the current study, the following activities are under way:

- characterizing and assessing the three coalmine lakes and the control lake for their suitability for sport fishery;
- identifying possible limiting factors for lake development;
- determining the time required for lakes to become stable;
- assessing levels of potentially harmful constituents, such as heavy metals; and
- evaluating various enhancement options to maintain or improve the coalmine lakes for fisheries habitat.

Last year, Luscar Ltd. completed a literature review and seasonal sampling of the three coalmine lakes. The limnological studies indicated that both Lovett and Silkstones lakes (those created by Luscar Sterco's Coal Valley mining operation) had changed since baseline studies had been done in 1989.

It was found that vertical mixing and water quality had improved, and the chemical and biological characteristics were similar to the natural control lake. It was expected that the productivity of both coal mining lakes should be acceptable. Conversely, Lac Des Roches, created by Cardinal River Coal Ltd., exhibited characteristics of an oligotrophic (low productivity) water body, largely owing to poor vertical mixing of water which prevents nutrients from being recycled.

Bathymetric Map of Lac Des Roches - A Coalmine Lake



(Source: Luscar Ltd.)

A one-year investigation of the fisheries potential of the three coal mining lakes was subcontracted to Pisces Environmental Consulting Services Ltd. of Red Deer. This company found that coarse rock dominated the shallow edge of Silkstone Lake, and it limited the diversity and distribution of aquatic plants. This means there is inadequate escape cover for fish in May and June. Also, significant numbers of fish in Silkstone Lake apparently leave the lake through a surface outlet. Nonetheless, an excellent growth rate was determined for rainbow trout that were released into the lake.

Lovett Lake was found to have fish-production characteristics that are similar to those of nearby natural lakes, and it was proposed that rainbow trout be introduced so their growth and survival could be monitored.

Based on the preliminary investigations, it was concluded that the physical characteristics and location of Lac Des Roches are more typical of high mountain lakes than of foothills lakes, although comparisons with other mountain lakes are difficult. It was found that this lake is capable of supporting a limited sport fishery. This conclusion is subject to change because the lake is young and has not yet reached equilibrium.

The project is being funded by Luscar Sterco (1977) Ltd., Cardinal River Coal Ltd., and the Alberta Office of Coal Research and Technology.

Publications

Luscar Ltd. 1992a. Development of Sport Fisheries in Lakes Created by Coal Mining Operations in the Eastern Slopes. Aquatic Macrophytes and Fish Population Characteristics. Progress Report #3. Prepared for Luscar Ltd. by Pisces Environmental Consulting Services Ltd.

Luscar Ltd. 1992b. Development of Sport Fisheries in Lakes Created by Coal Mining Operations in the Eastern Slopes. Limnological Characteristics of Study Lakes. Progress Report #2.

Luscar Ltd. 1991. Development, Characteristics and Management of Surface Coal Mine Lakes. Literature Review. Progress Report #1.

Coal As A Source of Value-Added Production and Feedstock

Since its inception in 1984, the Office has encouraged the development of new industries in Alberta based on coal. In years past, several projects, related mainly to coal mining and preparation, focused on developing new devices and machinery that might become the basis for manufacturing ventures in Alberta. More recently, the emphasis has been on processes that rely on coal as a feedstock. Three projects of this type were active in 1992/93, and are described in the following subsection.

Process Developments for Value-Added Products From Coal-Derived Pitch and Their Applications

ALBERTA RESEARCH COUNCIL, DEVON

In two previous studies, scientists at the Alberta Research Council (ARC) showed they could produce general purpose carbon fibre (GPCF) from the pitch produced when Battle River subbituminous coal was liquefied. Sufficient knowledge was gained in these two projects to conclude that a viable, commercial carbon fibre operation could be established in Alberta. Its principal market would be the cement industry where carbon fibres could be used in reinforced cement.

This year, a new project was begun. Its objectives were:

- to develop a process for making activated carbon fibre for use in water purifiers and air filters;
- to develop a process for making medium-strength, high-performance carbon fibre (HPCF) for the plastics industry; and
- to investigate applications for GPCF in reinforced cement.

Activated carbon fibre (ACF) was produced by exposing GPCF to either carbon dioxide or steam under conditions normally used to produce activated carbon. Measurements of the surface area and pore distribution of the activated products showed that ACF made under both reaction conditions had adequate surface area (up to 1 115 square metres per gram), and 88.2 per cent of the pore volume was concentrated in the micropore range. This makes them excellent candidates for use in gas storage, water purification and solvent recovery.

HPCF is used to reinforce certain types of plastics, particularly epoxy resins. These plastics are being used increasingly in automobile and aircraft parts and in engineering/construction materials.

HPCF can be made from the same pitch used to make GPCF, but the pitch must undergo some modification so that it contains 40-50 weight per cent liquid crystals and acquires suitable "spinnability" characteristics.

Experimental conditions were established for producing an HPCF having the required liquid crystal content. Three procedures were tried to make fine filaments by melt extrusion at 370°-410°C. All failed, apparently because of difficulties in controlling the temperature of the melt during extrusion.

A 0.5-kg sample of GPCF in the form of "felt" was produced from coal-derived pitch obtained from the liquefaction of Battle River

subbituminous coal. This sample was tested at the Civil Engineering Department of the University of Alberta for its suitability as a reinforcing agent in cement. For comparison, a commercial GPCF, made by the world's largest producer of GPCF, was also tested.

It was found that the specimens reinforced with the ARC-produced fibres had a lower flexural strength and toughness when compared with the commercial product. This difference in performance was attributed to the ARC fibres being shorter and having less consistent quality than the commercial fibres. It was also concluded that the commercial product was made from pitch that had been produced by a different process than was used at ARC.

The project was funded by the ARC and the Alberta Office of Coal Research and Technology.

Publication

Ohuchi, T., B. Croy and G. Kovacik. 1993. General Purpose Carbon Fibre (GPCF) and Its Applications. Final Report (1992-93). Alberta Research Council.

High-Value Products From Power Plant Ash

HALFERDAHL & ASSOCIATES LTD., EDMONTON

Although ash has been used as a construction material for centuries, the economic recovery of individual ash components has not been particularly successful despite the presence of potentially valuable materials in ash. Much of the attention thus far has been on the recovery of alumina, but the concentration of this material varies with the source coal. While magnetite and cenospheres (microscopic hollow glass spheres) have been recovered from ash in other locations, this has not occurred in Alberta.

Valued at up to $1 000 a tonne, and comprising approximately 4.5 per cent of some Alberta power plant ashes, cenospheres are worth investigating. Furthermore, some of these ashes contain quantities of titanium, boron and other rarer metals that might be recovered economically along with the alumina.

It has been estimated that coal-fired power plants in Alberta produce a total of 2.8 million tonnes of ash annually. Only 140 000 tonnes, however, are used profitably, primarily as a partial replacement for Portland cement. The remainder is regarded as a waste, requiring proper disposal. Disposal sites for these types of ash consume valuable land and incur costs that might otherwise be reduced if more ash could be used profitably.

Since ashes can differ in their chemical composition and mineralogy, the objective of a project initiated this year was to characterize selected ashes according to their chemical, physical and mineralogical properties, and to obtain information on processes for recovering potentially valuable products from them.

Bottom ash and flyash samples were collected at the Battle River and H.R. Milner power stations operated by Alberta Power Limited. These samples were submitted for analyses to the Department of Mining, Metallurgy and Petroleum Engineering at the University of Alberta, and to a private analytical laboratory in Vancouver and the Department of Chemistry at North Dakota State University. Physical, chemical and mineralogical properties were determined, as well as solubility in hot water and ability to be leached with hydrochloric acid. Also, beneficiation tests were carried out involving froth flotation, cenosphere separation and removal of magnetic fractions.

It was found that the two power plants produce ash having different characteristics. For example, Battle River flyash is described as "medium-calcium oxide", whereas the Milner flyash is low in calcium oxide (CaO). Many of the other chemical constituents and physical properties of the ashes varied between and within plants, depending on the sampling location.

It was concluded that while the Battle River ash has some potential for providing cenospheres, more needs to be learned about cenosphere recovery and markets. There is also some potential for recovering gold from the bottom ash. The ash from this plant might also be used as a mineral filler if the carbon, cenospheres and magnetite fractions are removed. Processes for recovering aluminum oxide should also be investigated.

The Milner plant might be capable of providing activated carbon, gold and magnetite.

Detailed analyses are provided in the 214-page final report.

The project was funded by Alberta Power Limited and the Alberta Office of Coal Research and Technology.

Publication

Halferdahl, L.B. and L.R. Plitt. 1993. High-Value Products from Power Plant Ash. Final Technical Report.

Clean-up of Soil Contaminated with Coal Tars/Heavy Residua

THERMO DESIGN ENGINEERING LTD., EDMONTON

The Office is one of several sponsors who have supported work at the Alberta Research Council (ARC) to develop technologies based on coal/oil agglomeration. One of these technologies, called the Clean Soil Process (CSP), can be used to clean up soil that has been contaminated with hydrocarbons. The principal advantage of CSP is its cost. While the operators of commercial incineration plants charge up to $1 700 per tonne (t) to handle contaminated soil, it has been estimated that the charges for CSP would be approximately $30-$70/t. The product resulting from CSP treatment, however, is not equivalent to that emerging from an incinerator. The CSP product requires further treatment to meet the clean-up criteria for some residual chemical compounds.

In an earlier study, it was shown from laboratory and bench-scale tests that thermal treatment was capable of providing this added level of clean-up by causing the undesirable compounds to desorb from the soil. Further, it was estimated that thermal desorption would raise the total costs of CSP treatment to $60-$150/t, which is still low by comparison with incineration. Given the significant potential for cost reduction vis-à-vis incineration, a project was initiated this year to construct a pilot-scale desorber to test the process on a larger scale and obtain the operating data needed to make more accurate cost estimates.

A mobile thermal desorption unit (TDU) capable of processing 500 kilogram per hour (kg/h) of hydrocarbon-contaminated soil was designed and built by Thermo Design Engineering Ltd. The unit is essentially a modified one tonne per hour Roto-Louvre coal dryer.

Following construction, the TDU was commissioned and tested at the ARC. These tests showed that control and stability of process temperatures were within acceptable ranges, and the material-handling characteristics were satisfactory. The tests also showed that modifications were necessary to lower the oxygen concentration in the flue gas. At year-end, these modifications were being made.

This project was supported by Thermo Design Engineering Ltd., the ARC and the Alberta Office of Coal Research and Technology.

Publication

Thermo Design Engineering Ltd. 1993. Clean-up of Soil Contaminated with Coal Tars/Heavy Residua. Volume I. Technology Description and Development of Thermal Post-treatment Process; Volume II. Operating Manual Mobile Thermal Desorption Unit.

Conferences

Since 1987, the Office has been sponsoring coal research conferences, symposia and workshops to help transfer to Alberta's coal industry the knowledge gained from Office-supported research. At the same time, these scientific gatherings are used as opportunities for the industry to propose suggestions for new research efforts. During 1992/93, two such conferences were supported by the Office and are described in the following subsection.

Coal Research Contractors' Conference

INFO-TECH CONFERENCE MANAGEMENT, CALGARY

On October 14, 1992, the Alberta Office of Coal Research and Technology sponsored a conference that featured presentations on research projects funded by the Office. This was the fourth such conference; all have been held in Calgary. Following the conference, the one-day Power Plant Ash Utilization Symposium was held.

Abstracts of both the conference and the symposium presentations are available from the Office on request.

Titles of the conference and symposium presentations are listed below.

Coal Mining and Upgrading

Variation of Elemental Distribution in Coal Seams from the Highvale Mine and Its Impact on the Environment, *T. Gentzis*

Comprehensive Coal Preparation Plant Performance Evaluation, *M.W. Mikhail*

Development of Sport Fisheries in Lakes Created by Coalmining Operations in the Eastern Slopes, *R. Latimer*

Coal/Oil Upgrader, *C. McKenny*

Coal Combustion and Gasification

International Energy Agency Annex II Coal Combustion Science Program, *G. Kovacik*

Canadian Coal Gasification R&D Project, *E. Furimsky/G. Kovacik*

Research on Stress Corrosion Cracking of Gasifier Vessel Steels in Coal Gasification Simulated Environment at The University of Calgary, *S.X. Mao*

Coal Use and the Environment

CO_2 Disposal Study; Phase II, *R. Bailey*

Feasibility of Aquifer Disposal of CO_2-rich Gases: A Proposal, *W.D. Gunter*

Comparative Analysis of Advanced Power Generation Cycles, *M. McDonald*

Thermal Desorber for Clean Soil Process Products Post-treatment, *K. Szymocha*

New Uses for Coal

Counterflow Reactor Development; Phase II, *D. Berger*

Co-processing of Coal and Heavy Oil in Alberta, *R. Bailey*

Evaluation of the Suitability of Coals for Blast Furnace Injection Based on a Computer Model, *W.P. Hutny*

Process Development for General Purpose Carbon Fibre (GPCF) From Coal-Derived Pitch, *T. Ohuchi*

Power Plant Ash Utilization Symposium

Coal Ash: An Overview, *D. Drysdale*

Ash Disposal: Regulatory Climate, Health Considerations and Disposal Design, *A. Hickinbotham*

The Use of By-products From Coal Combustion: The European Perspective, *A. Kodde*

High-Performance Concrete Incorporating Large Volumes of Ash, *V.M. Malhotra*

High-Volume Flyash: Polypropylene Fibre-Reinforced Shotcrete, *R. Morgan*

The Use of Flyash in Ready Mix Concrete: An Industry Perspective, *W. Fedirko*

High-Value Products From Power Plant Ash, *L. Halferdahl*

High-Volume Products: Use as Fill Material, *H.T. Chan*

Bucket Wheel Club Coal Workshop

ALBERTA RESEARCH COUNCIL, EDMONTON

The Bucket Wheel Club was formed by industry and government to promote the introduction of advanced technologies into Alberta's resource industries. The club derives its name from the successful introduction of Alberta-based advanced materials that were used on the teeth of bucket wheels. This caused a dramatic increase in teeth life and productivity of these machines. The club organizes workshops to bring together representatives of the resource industry and advanced technology companies.

On October 21-23, 1992, one of these workshops was organized on coal technologies. It was attended by 24 people who discussed opportunities in various aspects of the coal industry, including surface mining and reclamation, coal beneficiation, power generation, coal exports and coal transportation. It is anticipated that this meeting will result in research proposals in future years.

The project was supported by Alberta Research Council, Alberta Technology, Research and Telecommunications, Canada Centre for Mineral and Energy Technology, and the Alberta Office of Coal Research and Technology.

Western Canadian Low-Sulphur Coal Program

In 1987, the Premiers of Ontario and the three western coal-producing provinces and the Deputy Prime Minister established the Action Committee on Western Canadian Low-Sulphur Coal to Ontario. The purpose of the research program created by this committee is to reduce the delivered cost of western Canadian coals in Ontario and improve the quality of these coals.

The program is administered by an Intergovernmental Secretariat, comprising one representative from each of the five governments.

Of the 17 technical projects supported by the committee, Alberta was the lead agency for 13. Most of these projects have been completed; the three active in 1992/93 are described in the following section. The thrust of the program was expanded in 1992/93 to include local use of coal and export to markets outside Canada.

Coal/Oil Upgrader–Phase II

FORDING COAL LIMITED, CALGARY, AND OTHER PARTICIPANTS[1]

Large reserves of undeveloped subbituminous coals are found in eastern Alberta. Since these deposits are the closest in the province to markets in Ontario, and are located adjacent to both transcontinental railway lines, it is possible that they can be shipped to Ontario for less than other Alberta coals.

Because the deposits are near the surface of the overlying land, it is expected that mining costs will be low. There is a problem, however. The coal in these deposits has a high ash and moisture content.

Thus, a research project was begun two years ago to develop commercial-scale operation of a coal-upgrading process that originated with the Alberta Research Council (ARC). Called AGFLOTHERM, the process involves coal/oil agglomeration and uses subbituminous coal and heavy oil or bitumen. Studies carried out at ARC over several years involved a wide range of coals and heavy oils.

The results showed that the ash and moisture contents of the agglomerates can be 30-50 per cent lower than those of the parent coals. This improvement should result in coal having a calorific value in excess of 6 000 kilocalories per kilogram (kcal/kg) and be sufficient to make the subbituminous coals of eastern Alberta competitive in the Ontario marketplace. Furthermore, the upgrading process should be capable of producing a by-product oil having an API gravity of 19°-25°, which can readily be hydrotreated to synthetic crude oil specifications.

In the first phase of this project, a successful method for hydrotreating the by-product oil was found, and the optimum operating conditions were determined for a 225 kilogram per hour (kg/h) pilot-scale continuous deoiler, which was used to remove residual oil from the coal agglomerates. This work demonstrated that a thermal coal with a calorific value of 6 500 kcal/kg and an oil with an API gravity of 18°-18.5° could be produced. Bench-scale testing in a retort at UMATAC Industrial Processes in Calgary provided complete mass balances and defined the coal and oil products that might be expected from a larger operation. In addition, Allis Mineral Systems Inc. of Wisconsin carried out batch-scale pyroprocessing tests to determine the extent of problems, such as stickiness, that might be encountered in commercial-scale equipment.

Later, a pilot plant was built at the Allis Minerals Test Centre. It was used initially to deoil and dry coal/oil agglomerates produced at the ARC, and was subsequently used to deoil and dry a mixture of Genesee coal and Elk Point heavy oil. This mixture behaved like coal/oil agglomerates. In this case, the coal had been pre-cleaned by a proprietary process developed by Fording. This testing demonstrated that commercially proven equipment can be used to dry and deoil coal/oil mixtures. In particular, a hot shell (>700°C) in an indirect fired kiln was used to overcome handling problems in a "sticky temperature zone" that arose during earlier testing.

The test results were used to prepare a conceptual design for a commercial-scale upgrader.

Publications

Allis Mineral Systems. 1993. Equipment Option Comparison.

Allis Mineral Systems. 1992a. Report of Coal/Oil Upgrader Process Testwork for Fording Coal Limited.

Allis Mineral Systems. 1992b. Pilot Plant Test Reports. Coal/Oil Upgrader Project.

[1]Phase I was supported by Fording Coal Limited, PanCanadian Petroleum Limited, CANMET and the Alberta Office of Coal Research and Technology. Funding for Phase II was provided by Fording Coal Limited, PanCanadian Petroleum Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Carlson, D. 1993. Core Laboratories Analytical Report. Western Atlas International.

Kramer, J. 1992. Pilot Plant Report. 8 Tonne Agglomerate Production Run. Fording Coal Project.

Raymond, B. 1993a. Coal Heavy Oil Upgrader. Process Design Report.

Raymond. B. 1993b. Phase IIIb Summary Report. Coal Heavy Oil Upgrader. Raymond Mineral Dressing Consultants.

Raymond, B. 1993c. UMATAC Bench Scale Retort Testing (1993). Raymond Mineral Dressing Consultants.

Simpson, P.L. and R.J. Parker. 1993. Oil from Agglomerates Hydrotreating Study. Alberta Research Council.

Stanley Industrial Consultants Ltd. 1992. Vapours from Oil Recovery Sections of Agglomeration Pilot Facility. Prepared for Fording Coal Limited.

UMATAC Industrial Processes Ltd. 1992a. ATP Batch Scale Tests on the Fording Coal-Oil Agglomerate. Phase 1 Report.

UMATAC Industrial Processes Ltd. 1992b. AOSTRA Taciuk Process Phase 2 Batch Test Program on Coal/Oil Agglomerate. Results of Batch Testing on Samples Supplied by Fording Coal Limited.

Wheeler, C.J. 1993. Coal/Oil Upgrading. Condensibility of Coal/Oil Upgrader Product Gas. C.J. Wheeler Process Consultant Inc.

Wong, J.K., G.N. Banks and H. Whaley. 1993. Combustion Performance Tests on Fording Upgraded Coal Using CCRL's Pilot-Scale Research Boiler. CANMET.

Comprehensive Coal Preparation Plant Performance Evaluations

THE COAL ASSOCIATION OF CANADA, CALGARY

Studies in the U.S. and Australia have shown that the clean-coal yield of many coal preparation plants can be improved by one to five per cent by optimizing a plant's performance. Experience with one western Canadian coal company showed that an overall improvement of five per cent was possible, resulting in a substantial increase in revenues.

Because these improvements began with a comprehensive evaluation of individual preparation plants, a project was initiated in 1991/92 with the following objectives:

- to reduce the cost of producing merchantable coal by improving the recovery of clean coal;
- to reduce the environmental effects resulting from coal cleaning by reducing the volume of tailings that must be stored in ponds;
- to increase the overall recovery of coal;
- to establish baseline information on coal preparation plant performance in Canada; and
- to increase business opportunities for consultants and research organizations by defining the work needed to optimize plant operation.

Under direction of The Coal Association of Canada, staff of the Canada Centre For Mineral And Energy Technology's (CANMET) Western Research Laboratory at Devon sampled three coal preparation plants in Alberta and British Columbia. The collected samples were analysed for ash, moisture, solids content and float-sink properties. Some were tested for heat value. These analyses and material balances were used to evaluate each plant. Those plants that performed at or above their design capabilities were rated as successful. Those that operated below their design capabilities were examined closely, and recommendations were made for changes to the operation.

The recommended changes ranged from minor adjustments through major equipment modifications to overall optimizing of plants. Thus far, results have confirmed that improvements in yield of up to five per cent are achievable.

The project is being funded by the Department of Western Economic Diversification, the Alberta Office of Coal Research and Technology and individual Alberta-based coal companies.

Co-generation Study at the Obed Mountain Coalmine

LUSCAR LTD., EDMONTON

Reject coal and other forms of waste coal that cannot be sold become both a waste-disposal problem and a source of additional cost for mine operators. One solution to this problem is being explored in this project. It involves determining the economic and technical feasibility of building a co-generation plant at the Obed Mountain coalmine or in nearby Hinton. This facility, which would use waste coal as the fuel, would simultaneously produce heat and electricity. The principal sub-contractors, Monenco AGRA Inc., considered several options for using this heat and electricity. They ranged from a 10 megawatt (MW) plant at the mine site to a 100 MW plant located in Hinton.

Since Luscar is committed to using only a power plant that produces fewer emissions than are produced by conventional coal-fired power stations, the test facilities of CANMET near Ottawa were used to evaluate two types of combustion systems: pulverized coal firing and circulating fluidized-bed combustion. Coals from Obed and a reference thermal coal from the Coal Valley mine were used in these tests.

The combustion tests showed that the Obed coal performed well in both technologies, but it behaved better in the pulverized coal-fired system. The economic analysis suggested that the 100 MW option was the most promising and Hinton is the best market for heat and power.

The project was funded by Luscar Ltd., the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Publication

Monenco AGRA Inc. 1993. Preliminary Feasibility Study of Cogeneration at the Obed Mountain Coal Mine. Prepared for Luscar Ltd.

Project Expenditures

Table 1: Funding Contributions to Approved Projects by Year ($)

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
A/CERRF - COAL RESEARCH						
Resource Evaluation						
Creep Characteristics of Coal	16 459	-	-	-	-	16 459
Reflective Seismic Investigation of Western Canadian Coalfields	3 564	-	-	-	-	3 564
VLF Geophysical Methods in Coal Exploration	14 846	-	-	-	-	14 846
Geophysical Instrumentation	69 470	-	-	-	-	69 470
Geotechnical Properties of Overburden	71 501	-	-	-	-	71 501
Surface Geophysical Coal Exploration	333 468	-	-	-	-	333 468
3-D Structural Geometry	53 000	-	-	-	-	53 000
In-Seam Coal Characterization	236 824	-	-	-	-	236 824
Seismic Modelling of Shallow Coalfields	69 539	159	-	-	-	69 698
Downhole Geophysical Characterization of Overburden	179 266	-	-	-	-	179 266
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	73 835	47 094	146 842	-	-	267 771
Coal-Bed Methane: An Alberta Opportunity	-	-	40 000	-	-	40 000
SUBTOTAL: Resource Evaluation	1 121 772	47 253	186 842	0	0	1 355 867
Mining						
Support Design for Underground Cavities in Weak Rock	1 350	-	-	-	-	1 350
Coal Mining Research	1 955 562	-	-	-	-	1 955 562
Coal Mining in 2035	78 682	-	-	-	-	78 682
Triaxial Test Development	103 503	-	-	-	-	103 503
Ground Movements in Coal Mines	25 500	-	-	-	-	25 500
Mining 2035 Workshop	25 226	-	-	-	-	25 226
Robotics for Mine Control	96 178	-	-	-	-	96 178
Non-Cable Vehicle Guidance	133 455	-	-	-	-	133 455
Lasers in Coal Mining	50 954	-	-	-	-	50 954
Geostatistics	40 958	-	-	-	-	40 958
Footwall Anchoring	139 099	-	-	-	-	139 099

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
Time-Dependent Behaviour of Coal Measure Rocks	40 000	-	-	-	-	40 000
Deformation and Progressive Failure of Open-Pit Highwalls	84 702	-	-	-	-	84 702
Automated Machine Control for Optimized Mining (AMCOM)	197 222	-	-	-	-	197 222
Dragline Operations Monitor	40 225	-	-	-	-	40 225
SUBTOTAL: Mining	3 012 616	0	0	0	0	3 012 616
Preparation and Upgrading						
Beneficiation of Coal by Agglomeration in Pipelines	22 220	-	-	-	-	22 220
Coal Preparation Research	4 692 489	-	-	-	-	4 692 489
Coal Comminution	54 466	-	-	-	-	54 466
Numerical Analysis of Process Yield Losses	75 795	-	-	-	-	75 795
Advanced Processes for Low-Rank Coal	79 392	-	-	-	-	79 392
Properties of Thermally Dried Coals	144 459	-	-	-	-	144 459
Stabilization of Dried Coal	37 423	-	-	-	-	37 423
Agglomeration of Low-Rank Alberta Thermal Coals	130 785	-	-	-	-	130 785
Agglomeration for Beneficiation	49 772	-	-	-	-	49 772
Preparation and Upgrading Assistance to AOCRT	42 000	-	-	-	-	42 000
Moisture and Ash On-Stream Analyser	26 553	-	-	-	-	26 553
Recovery of Coal from Tailings	82 231	-	-	-	-	82 231
Fine Coal Technical Assistance	2 308	-	-	-	-	2 308
Froth Flotation Study at Coal Valley	29 237	-	-	-	-	29 237
Washery Optimization	220 978	-	-	-	-	220 978
Coal Beneficiation Process	907 439	-	-	-	-	907 439
Agglomeration of Coking Coal	90 000	-	-	-	-	90 000
Westcoal Separator Phase II	24 898	-	-	-	-	24 898
Coal Production Program Planning	36 750	6 484	-	-	-	43 234
Electrocoagulation	15 046	-	33 333	-	-	48 379
Coal Agglomeration Process Development	70 000	17 500	38 500	-	-	126 000

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
Particle Distribution in Slurry Flow Through Tees and Manifolds	53 222	43 570	16 178	-	-	112 970
Coal/Oil Upgrader	-	-	93 500	-	-	93 500
SUBTOTAL: Preparation and Upgrading	6 887 463	67 554	181 511	0	0	7 136 528
Combustion						
Combustion of Agglomerated Coal	33 336	-	-	-	-	33 336
Combustion Process Research	150 215	-	-	-	-	150 215
Combustion Characteristics of Alberta Coals	188 970	-	-	-	-	188 970
Combustibility of Agglomerates	14 156	-	-	-	-	14 156
Combustion Program Planning	76 604	-	-	-	-	76 604
Influence of Porosity on Combustion	84 000	-	-	-	-	84 000
Causes of Spontaneous Combustion of Western Canadian Coals	99 141	-	-	-	-	99 141
Combustibility of Upgraded Alberta Coals	115 000	-	-	-	-	115 000
Evaluation of Blending on Combustibility	36 000	-	-	-	-	36 000
Prediction of Coal Combustibility	147 416	-	-	-	-	147 416
Combustion Properties of Alberta Coals and Chars	150 000	-	-	-	-	150 000
Spontaneous Combustion of Thermally Treated Coals	25 503	-	-	-	-	25 503
International Energy Agency Basic Coal Combustion Science	465 564	-	-	-	-	465 564
A Thermodynamic Model for Spontaneous Combustion of Coal	54 567	40 918	-	-	-	95 485
Travel Grant to Study Sources of Ash in Controlled Conditions at IJumuiden	-	5 231	3 044	-	-	8 275
International Energy Agency Coal Combustion Science - Program Extension	-	94 640	102 383	210 944	60 000	467 967
Technology Transfer of IEA Coal Combustion Sciences Research	38 808	39 227	40 519	44 212	-	162 766
Ash Properties of Alberta Coals	-	49 962	148 638	-	-	198 600
SUBTOTAL: Combustion	1 679 280	229 978	294 584	255 156	60 000	2 518 998
Liquefaction/Co-processing						
Coal Liquefaction Study	151 864	-	-	-	-	151 864
Coal Liquefaction Feasibility Study	90 553	-	-	-	-	90 553

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
PYROSOL Process Review	7 006	-	-	-	-	7 006
Liquefaction Process Improvement	51 059	-	-	-	-	51 059
ENR/ARC Coal Conversion Research	14 342 349	-	-	-	-	14 342 349
New Liquefaction Processes	230 949	-	-	-	-	230 949
Preliminary Economic Evaluation of a Multistage Coal/Heavy Oil Co-processing Concept and Development of a Simple Process Evaluation	77 791	-	-	-	-	77 791
Isotopic Analysis of Co-processing Schemes	74 000	-	-	-	-	74 000
Secondary Upgrading	183 000	-	-	-	-	183 000
Functional Group Analysis of Coal Liquids	91 000	-	-	-	-	91 000
Chemistry of Coal Liquefaction	514 657	-	-	-	-	514 657
Secondary Upgrading of Co-processing Products	172 000	-	-	-	-	172 000
Supercritial Gas Extraction of Coal	82 276	-	-	-	-	82 276
Liquefaction of Coal with Natural Gas	35 750	-	-	-	-	35 750
Hydroprocessing of Coal-Derived Liquids	86 021	19 379	-	-	-	105 400
Isotopic Studies of Coal/Bitumen Co-processing	121 292	(566)	-	-	-	120 726
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	48 464	54 813	3 123	-	-	106 400
Product and Process Characterization	218 156	86 864	71 706	-	-	376 726
Co-processing Process Development	3 516 360	643 763	257 159	-	-	4 417 282
Combined Processing of Coal, Heavy Oil and Natural Gas	-	18 783	41 217	-	-	60 000
Specialty Chemicals from Coal-Derived Liquids	-	79 900	129 544	-	-	209 444
Process Development for Carbon Fibres from Coal-Derived Liquids	-	-	-	97 306	-	97 306
Co-processing of Coal with Molten Halide Catalysts	-	40 000	30 000	-	-	70 000
Co-processing of Coal and Heavy Oil in Alberta, Phase II	-	-	50 000	-	-	50 000

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
Coal/Oil Co-processing Using a Counterflow Reactor	-	-	296 369	-	-	296 369
SUBTOTAL: Liquefaction/Co-processing	20 094 547	942 936	879 118	97 306	0	22 013 907
Gasification						
Gasification of Western Canadian Coals	38 500	-	-	-	-	38 500
Fluidized Bed Gasification of Highvale Coal	64 201	-	-	-	-	64 201
Gasification Process Research	83 960	-	-	-	-	83 960
Gasification Properties of Alberta Coals	164 957	-	-	-	-	164 957
Gasification Laboratory Facilities	160 000	-	-	-	-	160 000
Corrosion in Gasification Systems	51 331	-	-	-	-	51 331
Gasification Characteristics of Alberta Coals	185 375	-	-	-	-	185 375
Devolatilization Properties of Alberta Coals	150 000	28 530	-	-	-	178 530
IGCC Utility Applications	-	25 000	-	-	-	25 000
Canada/Japan Collaboration in Coal Gasification Research	-	-	38 664	15 993	-	54 657
Gasification Properties of Alberta Coals	190 000	154 000	208 800	-	-	552 800
Stress Corrosion Cracking Evaluation in Coal Gasification Simulated Environment	-	-	-	-	11 190	11 190
Coal Combustion and Gasification Technology Monitoring and Transfer	-	-	-	-	47 767	47 767
SUBTOTAL: Gasification	1 088 324	207 530	247 464	15 993	58 957	1 618 268
Transportation						
Coal Slurry Pipeline Research	287 953	-	-	-	-	287 953
Coal Market Access Model	73 971	-	-	-	-	73 971
Coal-Oil Slurry Pipelining	659 909	-	-	-	-	659 909
Coal Slurry Technology	47 987	173 566	62 671	-	-	284 224
SUBTOTAL: Transportation	1 069 820	173 566	62 671	0	0	1 306 057
Environment						
Low NO_xSO_x Burner	50 028	-	-	-	-	50 028
Coal Conversion Waste-Water Treatment	64 000	-	-	-	-	64 000
Sorbent Injection Study	15 000	-	-	-	-	15 000

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
A State-of-the-Art Review on CO_2 Separation/Disposal Technologies	-	-	12 500	-	-	12 500
Gypsum as an Alternate Flocculent in the Treatment of Coal Mine Effluent Water	-	-	-	25 240	-	25 240
Investigation of Aquifer Disposal of CO_2 Rich Gases	-	-	-	-	29 871	29 871
NO_x Optimization of Sheerness #1	-	-	-	-	44 008	44 008
Full Fuel Cycle Emissions Analysis - Preliminary Review of Existing Studies	-	-	-	-	49 530	49 530
Comparative Analysis of Advanced Power Generation Cycles	-	-	-	-	25 000	25 000
Cost and Environmental Impact of Coal Liquid Fuels - Power Plants	-	-	-	-	50 000	50 000
Clean-up of Soil Contaminated with Coal Tars/Heavy Residua	-	-	-	-	103 000	103 000
SUBTOTAL: Environment	129 028	0	12 500	25 240	301 409	468 177
Markets						
Conversion from Oil to Coal-Water Fuels	35 806	-	-	-	-	35 806
Production of Activated Carbon	759	-	-	-	-	759
Activated Carbon from Coal	100 000	-	-	-	-	100 000
SUBTOTAL: Markets	136 565	0	0	0	0	136 565
Enhanced Oil Recovery						
Fuel Options for Enhanced Oil Recovery	15 000	-	-	-	-	15 000
Coal Use in Enhanced Oil Recovery	31 772	-	-	-	-	31 772
Coal-Fired Steam Injection Boiler	138 824	-	-	-	-	138 824
Application of the LNS Burner to an Oil Field Steam Generator	22 460	-	-	-	-	22 460
Economics of Coal Use for Heavy Oil Recovery	-	50 000	-	-	-	50 000
Coal/Condensate Slurry Pipelining	-	251 603	80 740	-	-	332 343
LNS Burner Steam Generator Demonstration	292 266	1 964 000	506 600	300 000	-	3 062 866
Coal/Condensate Slurry Pripeline Engineering Cost Study	-	-	25 311	-	-	25 311
SUBTOTAL: Enhanced Oil Recovery	500 322	2 265 603	612 651	300 000	0	3 678 576

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
Other						
Coal Technology Information Centre	571 120	-	-	-	-	571 120
CTIC Review	16 997	-	-	-	-	16 997
Data Gathering for Research Planning	51 996	-	-	-	-	51 996
Electrolysis of Coal Slurries	113 000	-	-	-	-	113 000
Sulphur Isotope Studies of Coal	63 200	-	-	-	-	63 200
Electrolysis of Coal Slurries II	48 497	11 503	-	-	-	60 000
Distributed Chemical and Physical Properties of Coal	39 423	12 538	-	-	-	51 961
Magnetic and Electric Properties of Alberta Coals	109 450	-	-	-	-	109 450
Distribution of Oxygen Forms in Western Canadian Low-Rank Coals	21 068	18 932	-	-	-	40 000
Evaluation of the Suitability of Alberta/Canadian Coals for Blast Furnace Injection	-	-	-	-	33 250	33 250
High Value Products from Power Plant Ash	-	-	-	-	14 000	14 000
Value Added Products from Coal Derived Pitch	-	-	-	-	72 457	72 457
SUBTOTAL: Other	1 034 751	42 973	0	0	119 707	1 197 431
SUBTOTAL: A/CERRF - COAL RESEARCH	**36 754 488**	**3 977 393**	**2 477 341**	**693 695**	**540 073**	**44 442 990**
A/CERRF - ALBERTA UNIVERSITIES PROGRAM						
Analysis of Coal-Bearing Strata Near Cadomin	20 000	-	-	-	-	20 000
Reflective Seismic Investigation of Western Canadian Coalfields	53 428	-	-	-	-	53 428
Support Design for Underground Cavities in Weak Rock	130 804	-	-	-	-	130 804
Coal Ash Monitoring System	71 633	-	-	-	-	71 633
Automedium Cyclones	95 711	-	-	-	-	95 711
Beneficiation of Coal by Agglomeration in Pipelines	185 414	-	-	-	-	185 414
Hydroprocessing of Coal-Based Liquids	84 936	-	-	-	-	84 936
Supercritical Gas Extraction of Coal	67 292	-	-	-	-	67 292

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
Coal Conversion Waste-Water Treatment	87 890	-	-	-	-	87 890
Production of Activated Carbon	39 441	-	-	-	-	39 441
SUBTOTAL: A/CERRF - ALBERTA UNIVERSITIES PROGRAM	**836 549**	**0**	**0**	**0**	**0**	**836 549**
DEPARTMENT-FUNDED PROJECTS						
Alberta Coal Geology Project	1 200 000	410 071	37 411	-	12 518	1 660 000
Smoky DENSECOAL Combustion Tests	9 560	-	-	-	-	9 560
Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment	-	-	-	55 982	18 509	74 491
Synthetic Fuels Program	48 220	-	-	-	-	48 220
Economic Evaluation of Coal/Oil Co-processing	48 117	-	-	-	-	48 117
Counterflow Reactor Development, Phase II	-	-	-	128 406	-	128 406
Coal Research Contractors' Conference	-	-	-	8 397	8 530	26 927
Economics of Coal Gasification	10 045	-	-	-	-	10 045
Corrosion in Gasification Systems	43 069	-	-	-	-	43 069
Canadian Coal Gasification R&D Project (CANMET/ARC)	-	-	-	210 000	150 000	360 000
Coal/Oil/Natural Gas Transportation System	25 000	-	-	-	-	25 000
Coal for Use in Enhanced Oil Recovery: Emission Control Technhology	14 625	-	-	-	-	14 625
CO_2 Disposal/Utilization Workshop	-	-	-	5 084	-	5 084
Development of Sport Fisheries in Lakes Created by Coal Mining Operations in the Eastern Slopes	-	-	-	21 740	4 686	26 426
CO_2 Disposal Study - Phase II	-	-	-	29 611	-	29 611
IEA Greenhouse Gas R&D Programme	-	-	-	162 000	9 180	171 180
Bucket Wheel Club Coal Workshop	-	-	-	-	5 000	5 000
SUBTOTAL: DEPARTMENT-FUNDED PROJECTS	**1 398 636**	**410 071**	**37 411**	**621 220**	**208 423**	**2 685 761**
TOTAL ALBERTA COAL RESEARCH	**38 989 673**	**4 387 464**	**2 514 752**	**1 314 915**	**748 496**	**47 965 300**

PROJECT TITLE	1977-89	1989/90	1990/91	1991/92	1992/93	TOTAL
WESTERN CANADIAN LOW-SULPHUR COAL TO ONTARIO PROGRAM						
Thick-Seam Extraction and Continuous Haulage Mining Demonstration	291 773	1 746 540	353 655	350 391	-	2 742 359
HYDROSIZER for Fine Coal Recovery from Tailings	21 000	-	-	-	-	21 000
Testing of ARCOFLUX 130	5 040	-	-	-	-	5 040
Air-Sparged Hydrocyclone	41 577	86 354	-	-	-	127 931
On-Line Coal Analysers	-	83 733	-	-	-	83 733
Tailings Reclamation	3 649	25 182	8 380	6 560	-	43 771
Developing a Practical Model for the Compound Water Cyclone	-	-	56 288	-	-	56 288
Thermal Drying of Western Canadian Low-Rank Coals	-	-	9 283	-	-	9 283
Coal/Oil Upgrader - Phase II	-	-	-	306 000	893 999	1 199 999
Comprehensive Coal Preparation Plant Performance Evaluations	-	-	-	46 943	35 954	82 897
transCOM Co-ordinated Vendor Test	-	296 623	51 452	-	-	348 075
Feasibility Study - IGCC Power Plant	-	-	124 167	-	-	124 167
Cogeneration Study at the Obed Mountain Coal Mine	-	-	-	-	73 816	73 816
TOTAL: WESTERN CANADIAN LOW-SULPHUR COAL TO ONTARIO PROGRAM	**363 039**	**2 238 432**	**603 225**	**709 894**	**1 003 769**	**4 918 359**
TOTAL: COAL RESEARCH PROGRAMS	**39 352 712**	**6 625 896**	**3 117 977**	**2 024 809**	**1 752 265**	**52 883 659**
PROGRAM ADMINISTRATION	-	90 699	105 409	215 118	131 242	542 468

Appendix

Projects Supported by the Alberta Office of Coal Research and Technology in 1992/93

Department-Funded Projects

Project	*Researcher*	*Status*
Clean-Coal Technologies for Electrical Power Production in Alberta		
International Energy Agency Coal Combustion Science–Program Extension	Netherlands Energy Research Foundation	Continuing
Coal Combustion and Gasification: Technology Transfer and Monitoring	Alberta Research Council	Continuing
Comparative Analysis of Advanced Power Generation Cycles	Canadian Electrical Association	Completed in 1992/93
NO_x Optimization on Sheerness Unit #2	Alberta Power Limited and TransAlta Utilities Corporation	Continuing
Full Fuel-Cycle Emissions Analysis–Preliminary Review of Existing Studies	Monenco Inc.	Completed in 1992/93
Canadian Coal Gasification R&D Project (CANMET/ARC)	CANMET	Continuing
Stress Corrosion Cracking Evaluation in Coal Gasification Simulated Environment	The University of Calgary	Continuing
IEA Greenhouse Gas R&D Programme	International Energy Agency	Continuing
Investigation of Aquifer Disposal of CO_2-Rich Gases	Stanley Industrial Consultants Ltd. and Alberta Research Council	Completed in 1992/93
CO_2 Disposal Study - Phase II	Alberta Oil Sands Technology and Research Authority and Others	Continuing
Technologies to Enhance the Export of Alberta Coals		
Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment	Alberta Research Council	Completed in 1992/93
Evaluation of the Suitability of Alberta/Canadian Coal for Blast Furnace Injection	CANMET	Completed in 1992/93
A Comparative Study of the Cost and Environmental Benefits of Coal-Liquid Fuel and Coal Preparation and Utilization in Electric Power Plants	Canadian Electrical Association	Completed in 1992/93

Project	*Researcher*	*Status*
Development of Sport Fisheries in Lakes Created by Coal Mining Operations in the Eastern Slopes	Luscar Sterco (1977) Ltd.	Continuing
Coal As A Source of Value-Added Production and Feedstock		
Process Developments for Value-Added Products From Coal-Derived Pitch and Their Applications	Alberta Research Council	Completed in 1992/93
High-Value Products From Power Plant Ash	Halferdahl & Associates Ltd.	Completed in 1992/93
Clean-up of Soil Contaminated with Coal Tars/Heavy Residua	Thermo Design Engineering Ltd.	Completed in 1992/93
Conferences		
Coal Research Contractors' Conference	Info-Tech Conference Management	Completed in 1992/93
Bucket Wheel Club Coal Workshop	Alberta Research Council	Completed in 1992/93

Western Canadian Low-Sulphur Coal Program

Project	*Researcher*	*Status*
Coal/Oil Upgrader - Phase II	Fording Coal Limited and Others	Continuing
Comprehensive Coal Preparation Plant Performance Evaluations	The Coal Association of Canada	Continuing
Co-generation Study at the Obed Mountain Coalmine	Luscar Ltd.	Completed in 1992/93

Currently available publications:

Alberta Coal: Energy for the World. 27 pages, August 1987.

Annual Review 1984/85, Alberta Office of Coal Research and Technology. 24 pages, 1985.

Annual Review 1985/86, Alberta Office of Coal Research and Technology. 26 pages, 1986.

Annual Review 1986/87, Alberta Office of Coal Research and Technology. 32 pages, 1988.

Annual Review 1987/88, Alberta Office of Coal Research and Technology. 62 pages, 1989.

Annual Review 1988/89, Alberta Office of Coal Research and Technology. 60 pages, 1990.

Annual Review 1989/90, Alberta Office of Coal Research and Technology. 62 pages, 1991.

Annual Review 1990/91, Alberta Office of Coal Research and Technology. 56 pages, 1991.

Annual Review 1991/92, Alberta Office of Coal Research and Technology. 74 pages, 1992.
An Economic Analysis of Coal Pipeline Systems. 6 pages, January 1987.

Opportunities to Use Coal in Enhanced Oil Recovery. 8 pages, May 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals. 14 pages, June 1988.

Gasification of Western Canadian Coals. 14 pages, June 1988.

Coal Research Centre, Devon. 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals. 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones. 10 pages, January 1989.

The Technical Committee Approach to Coal Research. 6 pages, January 1989.

Advanced Coal Mining Techniques for Alberta. 10 pages, March 1989.

Some Combustion Studies of Alberta Coals. 13 pages, May 1989.

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Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery. 8 pages, November 1989.

Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals. 10 pages, November 1989.

Methods for Producing Liquid Hydrocarbons from Coal. 17 pages, March 1990.

Geotechnical Studies of Overburden and Coal at Alberta Coal Mines. 14 pages, October 1990.

Studies of Some Fundamental Properties of Coal and Potential Uses for Coal. 11 pages, August 1991.

Studies of Coal Slurry Systems and Alternative Coal Transportation Methods. 12 pages, January 1992.

Some Studies of Alberta's Coal Geology. 12 pages, January 1992.

Some Recent Studies of Coal Combustion and Gasification. 19 pages, February 1992.

Recent Studies of Coal Mining, Cleaning and Upgrading. 13 pages, February 1992.

Development of Geophysical Methods for Coal Exploration in Alberta. 19 pages, February 1992.

Methods for Producing and Upgrading Liquid Hydrocarbons from Alberta Coal. 21 pages, May 1992.

Development of DENSECOAL Fuels Using Alberta Coals. 14 pages, October 1992.

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